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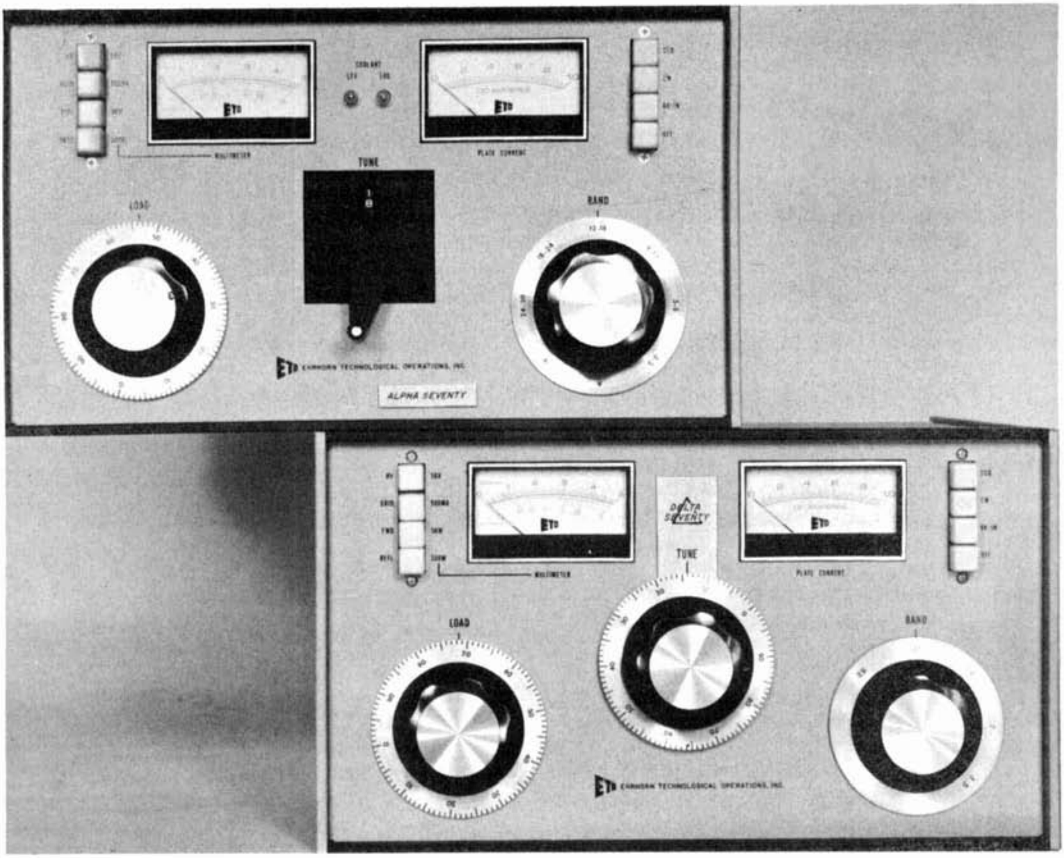
FEBRUARY 1971

ETCHED·INDUCTANCE

bandpass filters and filter-preamps for 50 and 144 MHz

this month



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February, 1971
volume 4, number 2

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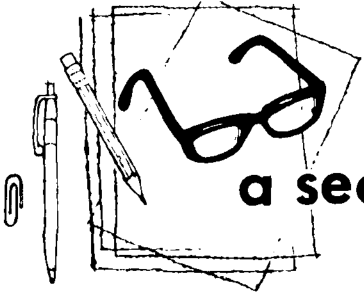

a second look

by jim fisk

As I mentioned in this column several months ago, microminiaturization is forcing inductors out of electronic circuitry. The sad fact of the matter is that it is virtually impossible to compress the inductor. Current inductance designs are much too large to fit into the rest of the circuit, and if the inductor is shrunk too much, performance rapidly deteriorates. Several ingenius substitutes have turned up to replace this bulky component: surface-wave devices (discussed in the September, 1970 issue of *ham radio*), active filters, integrated-circuit phase-locked loops, capacitor-loaded gyrators and etched-circuit inductors.

etched inductors

Although the etched-circuit inductor is still much too large for many applications, it results in considerable space saving, and unlike some of the other inductor substitutes, etched inductors can be easily built in the amateur workshop. One excellent application of etched inductors is discussed by W5KHT in his article on 6- and 2-meter bandpass filters and preamplifiers in this issue. Since writing the article, Bob has come up with a similar design for 220 MHz, as well as a completely etched-circuit two-meter converter that includes printed-circuit inductors. If there is sufficient reader interest in the etched-inductor two-meter converter, we will publish full details in an early issue.

Although printed-circuit spiral-shaped inductors are not new, they have seen limited use, even in commercial and military equipment. However, now that the ice has been broken, I suspect we will be seeing more and more of these inductors in amateur-built equipment.

The inductance of an etched inductor depends upon surface area of the spiral, conductor width, length of the spiral and number of turns. Since it's a rather complex calculation, the best bet is cut and try. One of the best materials for experimenting with etched inductors is the adhesive-backed copper-foil strip available from Cir-Kit. This material can be easily arranged into the square spiral, increasing the number of turns to increase inductance. Once you have arrived at the proper number of turns for your application, you may translate the design to a printed-circuit board if you want.

other techniques

The gyrator is a directional phase changer in which phase changes in opposite directions differ by 180 degrees. When loaded with a capacitor it has all the electrical characteristics of an inductor. Present integrated-circuit gyrators simulate inductance over the frequency range from dc to 20 kHz with stable Qs up to 1800. However, experimental designs at Bell Labs have provided adequate temperature stability and Q up to 100 MHz.

More work needs to be done before practical high-frequency gyrators are a reality, but research has been slowed by the high success of active filters that use low-cost ic operational amplifiers. Integrated-circuit phase-locked loops are also being used for miniature resonant circuits, as are surface-wave devices and micro-crystal filters. At this point in time it is difficult to guess which technique will provide the tuned circuits for the miniature communications equipment of the future, but lab work in the next decade probably toll the end of the inductor as we know it today.

Jim Fisk, W1DTY
editor

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More Details? CHECK—OFF Page 94

etched-inductance bandpass filters and filter-preamplifiers for 50 and 144 MHz

Easy to build, high-performance, narrow-bandwidth interdigital filters and bandpass preamplifiers that feature etched-circuit inductors

Bob Cooper, W5KHT

Although etched-circuit inductances have been around for over 40 years, very little has appeared in amateur radio publications. In 1929, Charles Ryder, an Australian, was granted a patent[1] that covered the earliest known application of an inductance, "applied by printing, gold blocking, painting, metal spraying or electro-deposition to the surface of a dielectric base."

In a sense, the Ryder invention was the forerunner of all modern-day printed-circuit devices, but more particularly, the thin-film etched inductances used in microwave integrated circuits. As a mass-production technique. etched inductances are about the neatest thing to come down the electronics pike since the transistor.

In the August, 1970 issue of *ham radio* I described an interdigital preamplifier[2] that married a grounded-gate fet preamplifier to a pair of comb-line filters. The resulting system produced a narrow-passband preamplifier that reduced overload and cross-modulation problems in high performance low-noise vhf converters.

After putting together a number of these units, it became apparent that although the completed devices were electrically adequate, any mass production for commercial use was unlikely because too much hand labor was required in their construction and alignment. The search was on for a mass-production technique that would provide the same performance as the costly hand-built strip-line unit. The etched-circuit Interdigital Series Bandpass Filters and Interdigital Preamplifiers described in this article are a result of that search.

bandpass filter circuit

The circuit shown in **fig. 1** was developed to satisfy the requirement for a bandpass filter which could be placed ahead of one or more grounded-gate fet amplifiers. This circuit* is a variation of the three-element T-section bandpass filter. The circuit was developed specifically for the etched-circuit inductance system, and interestingly enough, it almost is impossible to make it work without etched inductors.

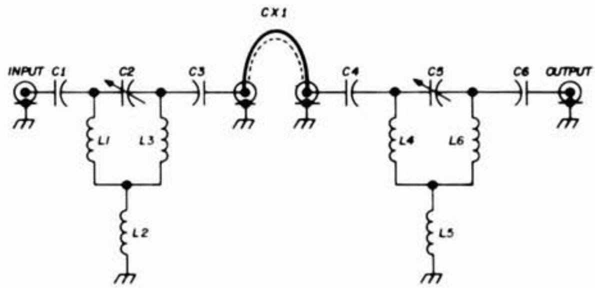


fig. 1. Circuit diagram of the interdigital series bandpass filter. Component values for 50 and 144 MHz are given in tables 1 and 2.

table 1. Parts list for the 50-MHz interdigital bandpass filters.

C1, C3, C4, C6 6.0 pF, 5% disc or tubular ceramic capacitors

C2, C5 4-40 pF midget trimmers (Elmenco-Arco type 422)

L1, L3, L4, L6 etched inductances on printed-circuit board (fig. 3)

L2, L5 15 turns no. 16 solid copper, closewound on 1/4-inch form, with last two turns (ground side) separated from balance of coil by one turn width

CX 2½ inches RG-58/U coaxial cable, with braid twisted into pigtails so that total length of inner dielectric is 1-3/4 inches; pigtails are 1/2-inch long

table 2. Parts list for the 144-MHz interdigital bandpass filters.

C1, C3, C4, C6 2.2 pF, 5% disc or tubular ceramic capacitors

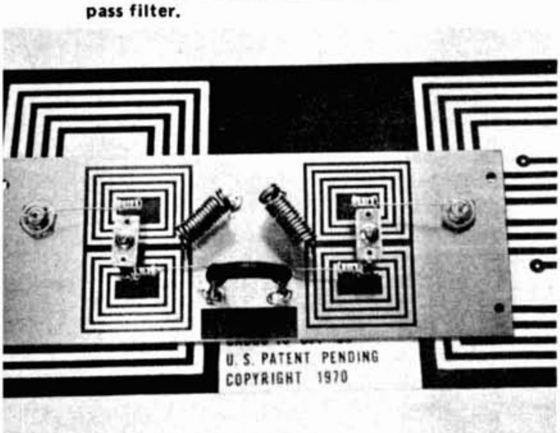
C2, C5 4-40 pF midget trimmers (Elmenco-Arco type 422)

L1, L3, L4, L6 etched inductances on printed-circuit board (fig. 4)

L2, L5 5 turns no. 16 solid copper, closewound on 1/4-inch form with 0.2 inch standoff pigtails

CX 2-1/2 inches RG-58/U coaxial cable, with braid twisted into pigtails so that total length of inner dielectric is 1-3/4 inches long; pigtails are 1/2-inch long.

50-MHz etched-inductance bandpass filter.



In the circuit shown in **fig. 1**, two mirror-image three-section capacitively-tuned T-section filters are cascaded through a short length of coaxial cable. By careful selection of L3, L6, C1, C3, C4 and C6, the bandpass window can be

*The information presented here covers relatively narrow bandpass devices suitable for amateur applications. Etched-inductance interdigital bandpass filters and etched-inductance interdigital preamplifiers are the subject of patent applications filed by the author. Amateur construction of the units shown here for personal use will not violate the validity claims of the pending patents. **editor.**

varied from as narrow as 250 kHz at 50 MHz to as wide as 10 MHz at 200 MHz (or as narrow as 1.0 MHz at 200 MHz to as wide as 10 MHz at 50 MHz). Insertion losses are as low as 0.75 dB at either frequency.

In addition, the filter can be tuned so that is has very steep skirts on just one side (**fig. 2A**), or steep skirts on both sides (**fig. 2B**). Once the components have been selected, total alignment time with a sweep generator is about 5 minutes. If you don't have a sweep generator and marker oscillator, the unit can be aligned with nothing more exotic than a signal source and a receiver S-meter – in just about the same amount of time.

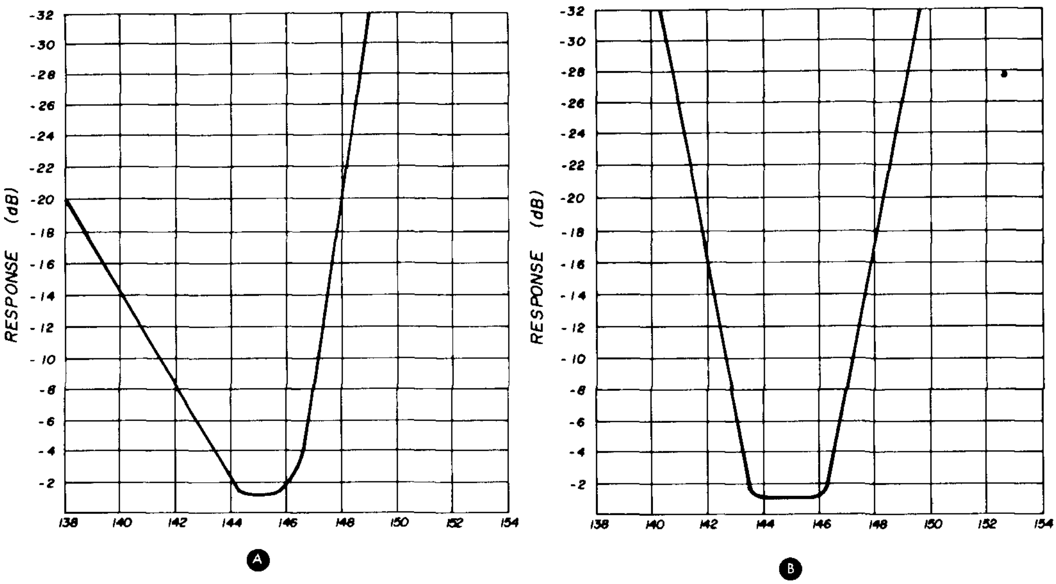


fig. 2. Bandpass characteristics of the 144-MHz etched-inductance bandpass filter. Filter may be adjusted for steep skirts on one side (A) or both sides (B).

table 3. Component values for narrow-band versions of the bandpass filters.

50 MHz

C1, C3, C4, C6 4.5 pF, 5% disc or tubular ceramic capacitors

L2, L5 16 turns no. 16 solid copper, close-wound on 1/4-inch form, separating two turns from balance of coil by one turn width

144 MHz

C1, C3, C4, C6 1.8 pF, 5% disc or tubular ceramic capacitors

L2, L5 6 turns no. 16 solid copper, close-wound on 1/4-inch form with 0.2-inch standoff pigtails

Etched-inductance interdigital bandpass filters for 50 and 144 MHz are shown in the photographs. A half-size layout of the 50-MHz board is shown in **fig. 3;** a half-size layout of the 144-MHz board is shown in **fig. 4.** Parts lists for the two boards are given in **tables 1** and **2,** respectively, for the 50- and 144-MHz filters. Commercially-made printed-circuit boards and complete parts kits are available.*

The 50-MHz filter has a 3-dB bandwidth of 1.0 MHz, centered on 50.250 MHz. The insertion loss between 49.8 and 50.7 MHz is 1.0 dB or less; filter rejection at 55.25 MHz (channel 2 video carrier) is as high as 40 dB. This should provide adequate front-end protection under the most taxing cases of channel-2 interference. If not, two filters may be cascaded together for up to 60-dB suppression of the 55.25-MHz signal. Insertion loss with two cascaded filters is approximately 2 dB.

MHz away from the center frequency will be on the order of 30 to 40 dB. A list of parts for the narrow-passband models of these filters is given in **table 3.**

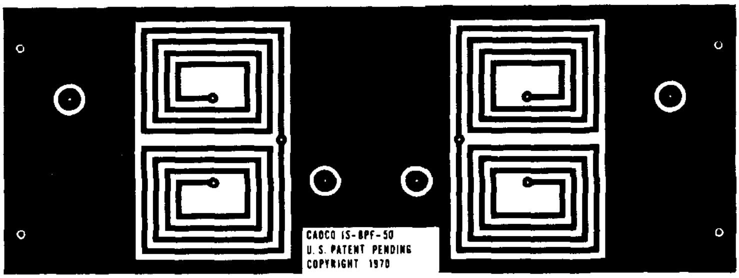


fig. 3. Half-size layout of the 50-MHz bandpass filter board.

The 144-MHz filter has a 3-dB bandwidth of 3.0 MHz, centered on 145 MHz. Insertion loss between 144.0 and 146.0 MHz is on the order of 1.0 to 1.5 dB, depending somewhat on the quality of the parts used in the filter. The bandpass skirts are very sharp, dropping down 3 dB at 143.5 and 146.5 MHz, and down 30 to 35 dB at 140 and 150 MHz.

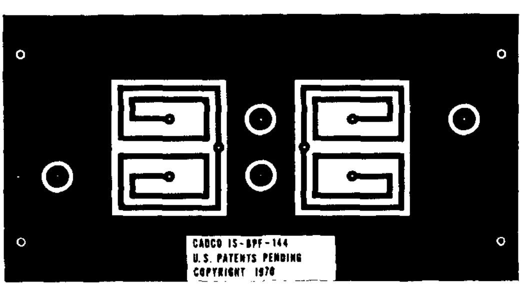
In either of the filters the width of the passband may be designed to cover a much narrower range: 250 kHz at either 50 or 144 MHz. In this case, rejection 3

parts selection

Capacitors C1, C3, C4 and C6 determine the width of the passband as well as playing a part in establishing the operating frequency of the filter. Ceramic discs are adequate for these capacitors, provided leads are short, with direct point-to-point wiring. The capacitance values are very important. If a 2.7 pF ceramic disc is specified, only 2.7 pF will work – 2.5 or 3.0 pF *will not.* Five percent capacitors recommended.

Inductors L1 and L3 are the fixed etched inductances. L2 is an airwound inductance used for fine adjustments. As L2 is varied from maximum to minimum inductance, the operating frequency moves upward from 120 to 165 MHz.

fig. 4. Half-size layout of the 144-MHz bandpass filter board.



*Complete boards, as well as complete parts kits with boards, are available from CADCO, Suite 107, 4444 Classen Boulevard, Oklahoma City, Oklahoma 73118. 50-MHz bandpass-filter board, $6.00; 50-MHz bandpass-filter kit, BPF-50, $11.00; 50-MHz preamp board, $8.00; 50-MHz preamplifier kit, IPA-50, $19.50. 144-MHz bandpass-filter board, $6.00; 144-MHz bandpass-filter kit, BPF-144, $11.00; 144-MHz preamplifier board, $8.00; 144-MHz preamplifier kit, IPA-144, $19.50. All prices are postpaid in the U. S. A. If you order a complete kit and want the narrow-bandwidth version, simply specify "narrow band;" no price change.

Correct values of C1, C3, C4 and C6 vary from approximately 2.9 pF at 120 MHz to 2.4 pF at 165 MHz. If the values of C1, C3, C4 and C6 are too *large,* the width of the bandpass window will be too great for amateur applications; if the capacitance values are too small, the passband will be too narrow, and the insertion loss will be unnecessarily high.

Variable capacitors C2 and C5 are Arco-Elmenco trimmers; the printed-circuit board has been designed with their physical dimensions in mind.

The coaxial loop between C3 and C4 is a short length of RG-58/U coaxial cable. *Do not* try to replace this loop with another type of coaxial cable, or with a low-value coupling capacitor.*

tuning the bandpass filter

The etched-circuit bandpass filter may be aligned with a sweep generator and marker oscillator, or with a simple signal source (signal or marker generator).

Sweep generator/markers. Connect a broadband sweep generator to the input of the filter through a mixer device as shown in **fig. 5.** The mixer combines the sweep and marker signals into one composite signal that drives the filter (the mixer is not required for sweep generators which use an internal marker oscillator). The output of the filter is fed to a detector that demodulates the signal for the oscilloscope display.

*For 75-ohm systems the RG-58/U coaxial cable may be replaced with a section of RG-59/U. No other circuit changes are necessary.

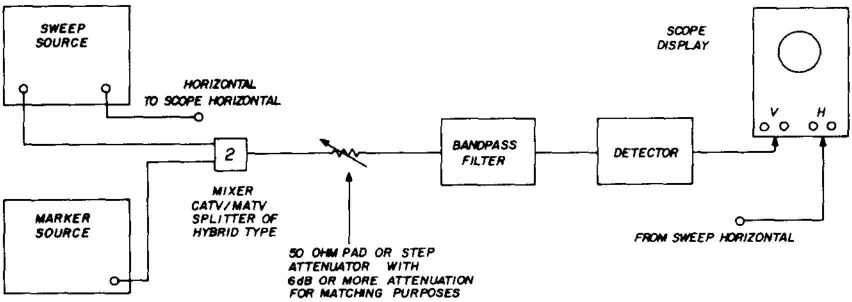


fig. 5. Test setup for aligning the etched-inductance bandpass filters.

Put the marker on the desired *center* frequency and tune C2 and C5 for maximum signal at the center of the passband. Now move the marker to the predicted 3-dB down point on the low side of the passband, and adjust C2 for maximum rejection. Your center frequency point *should not move up or down in frequency* as you do this.

Finally, move the marker to the predicted 3-dB down point on the high side of the passband, and adjust C5 for maximum rejection. Again, the center of the passband *should remain centered* on the display.

Disconnect the sweep generator; with the marker at the center frequency of the filter, feed the marker signal directly into the filter. Connect the output of the filter to your receiver and read the level of the marker signal on the S-meter. (It is advisable to attenuate the marker output so the S-meter indication is in the range of S5 to S7, normally the receiver's most linear region.) Now connect the marker oscillator to the receiver and read the S-meter. The difference between the two S-meter readings is the insertion loss of the filter. If everything is adjusted properly, the 1.0- to 1.0-dB insertion loss won't even be noticed on the S-meter.

Marker or signal generator. The alignment process with a marker or signal generator is essentially the same as that with a sweep generator. First, tune the filter for maximum signal at the center passband frequency. Check filter and no-filter S-meter readings as you progress to see when you get down to the level of 1- to 2-dB insertion loss. Move the signal generator to the lower 3-dB down frequency and adjust C2 for maximum rejection (go back to the center frequency to make sure it hasn't moved too). Now move the generator up to the upper 3-dB down frequency, adjusting C5 for maximum rejection. Finally, check insertion loss to make sure it is still less than 2.0 dB.

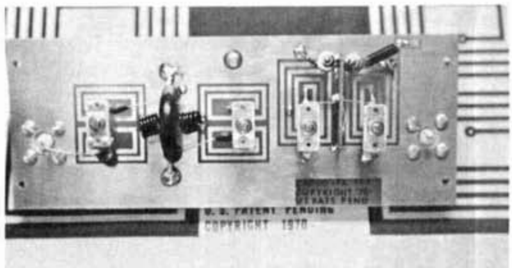
This bandpass filter arrangement uses fewer components, no shielded component sub-sections, and tunes up much easier than any other design that I am aware of. If it appears that you are having trouble holding the center passband frequency in place as you vary C2 and C5, try spreading a few turns of L5, and returning to the center frequency. (Spread the center of L5 apart about one extra turn width to start.) The change in L5 will compensate for slight unbalances between the twin sections of L1-L3 and L4-L6 that may exist because of differences between the fixed ceramic capacitors.

two-meter etched-inductance preamp

The two-meter etched-inductance preamplifier shown in the photograph consists of an etched-inductance bandpass filter and a single-stage grounded-gate fet amplifier. The circuit is shown in **fig. 6.** At 144 MHz the gain of this device is 10 to 12 dB, and the noise figure is 1.4 to 1.6 dB. A similar unit for 50 MHz will produce 10 to 12 dB gain with a noise figure of 1.0 dB of less.* Half-size circuit-board layouts for 50 and 144 MHz are shown in **figs. 7** and **8** respectively.

A Siliconix 2N5397 fet was used in the original interdigital preamplifier described in the August issue.[2] Since that time Siliconix has introduced a low-cost plastic version of this device, the E-300. The price of the new E-300 is $2.00 in small quantities, as opposed to $5.50 for the 2N5397.

In the photograph you can see that the input inductance to the fet (L7 in **fig. 5**) is isolated from the output inductance (L8 in **fig. 5**) by a piece of double-sided copper-clad printed-circuit board. In addition to serving as a shield, this section of board is a mounting plate for the E-300 fet. The shield is soldered to the 1/8-inch strip of copper between L7 and L8; the E-300 gate lead is soldered to the L8 side of the shield with the transistor mounted inside a 3/8-inch mounting hole (see **fig. 9**).



144-MHz interdigital preamplifier. The filter section is to the left side of the board, the fet preamplifier to the right.

Capacitor C6 feeds the input of the preamplifier. On both versions, C6 is tapped onto L7 at the point indicated by the dot in **fig. 7** and **8.** C6 should be routed from the output end of L6 to the input of L7 **under** the printed-circuit board. This is the only part mounted under the board.

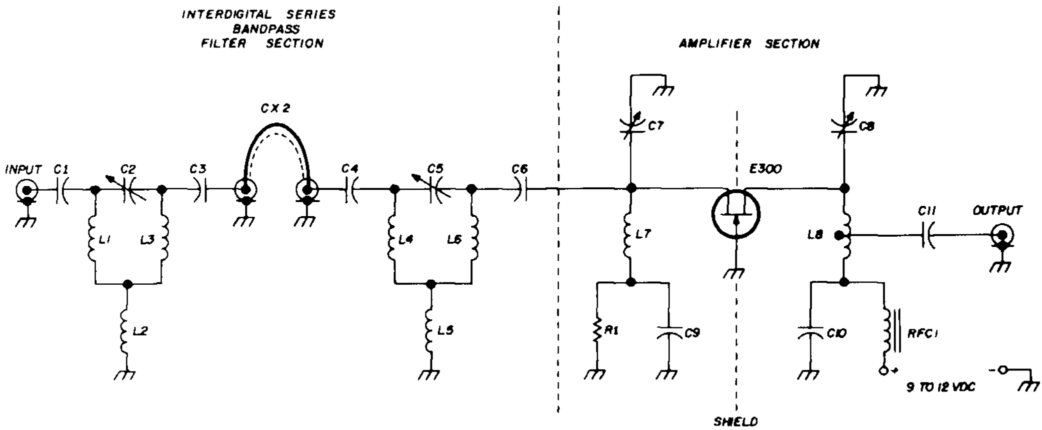
Capacitors C7 and C8 are Arco-Elmenco trimmers, and resonate with inductances L7 and L8. L7 and L8 are

*Since noise is wideband, a broad rf amplifier reacts to noise not only within the desired range of frequencies, but to noise outside that range as well. The steep skirted bandpass filter contributes measureably to an overall noise reduction in the communications system because the noise seen by the receiver is limited to that noise within the passband of the filter. As a consequence, the mixer is hit only with in-band noise, and while difficult to measure accurately, the receiver seems less prone to noise blocking.

bypassed to ground with BH-140 stud-type capacitors mounted at the outside end of the etched inductances. The BH-140 capacitors are mounted upside down, with the solder tab soldered to the end of the shield. Ceramic button bypass capacitors could also be used for this purpose.

Resistor R1 is chosen for correct fet operating current. This 1/4-watt resistor is mounted with very short leads from the outside end of L7 to ground, and placed against the shield at the C9 soldering point. The proper value for R1 is determined by placing a milliammeter in series with the dc supply (9 to 12 volts) and adjusting the resistance for 5-mA drain current; this is the proper current drain for both minimum noise figure *and* maximum gain. The correct value usually falls

fig. 6. Etched-inductance interdigital preamplifier for 50 or 144 MHz.



50-MHz bandpass preamplifier

C1, C3, C4, C6 6.0 pF, 5% disc or tubular ceramic capacitor

C2, C5, C7, C8 4 — 40 pF midget trimmer (Elmenco-Arco type 422)

C9, C10 500-pF stud-type uhf bypass capacitors (Sprague type BH-140)

C11 500-pF disc ceramic capacitor

L1, L3, L4, L6, L7, L8 etched inductances on printed-circuit board (fig. 8)

L2, L5 15 turns no. 16 solid copper, close-wound on 1/4-inch form, with last two turns (ground end) separated from balance of coil by one turn width

R1 91 to 560 ohms, 1/4-watt (see text)

RFC1 Ohmite Z-50 rf choke (7.0 μH) or equivalent

CX 2-1/2 inches RG-58/U coaxial cable, with braid twisted into pigtails so that total length of inner dielectric is 1-3/4 inches; pigtails are 1/2-inch long

144-MHz bandpass preamplifier

C1, C3, C4, C6 2.2 pF, 5% disc or tubular ceramic capacitors

C2, C5, C7, C8 4-40 pF midget trimmers (Elmenco-Arco type 422)

C9, C10 500-pF stud-type uhf bypass capacitors (Sprague type BH-140)

C11 500-pF disc ceramic capacitor

L1, L3, L4, L6, L7, L8 etched inductances on printed-circuit board (fig. 9)

L2, L5 5 turns no. 16 solid copper, close-wound on 1/4-inch form with 0.2 inch standoff pigtails

R1 91 to 560 ohms, 1/4-watt (see text)

RFC1 Ohmite Z-144 rf choke (1.8 μH) or equivalent

CX 2-1/2 inches RG-58/U coaxial cable, with braid twisted into pigtails so that total length of inner dielectric is 1-3/4 inches; pigtails are 1/2-inch long between 100 and 560 ohms, with 200 to 400 ohms being common.

RFC1 is an Ohmite Z-144 or Z-50; although their current-carrying capacity isn't required for this application. Any good quality wirewound rf choke with the same inductance value as the Z-50 (7.0 μH) or Z-144 (1.8 μH) will do. Since L8 is bypassed to ground with the 500-pF BH-140 there's not much chance of an rf problem anyway, but it's good practice to include the rf choke in the circuit.

The output coupling capacitor is a 500-pF disc ceramic. This capacitor is tapped onto L8 fairly close to the point where C10 is attached to the outer end of the inductance. A small dot on **figs. 7** and **8** indicates the approximate tap point for maximum preamplifier gain.

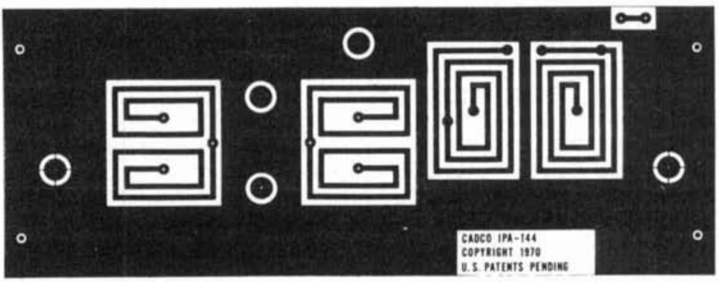
preamplifier tuneup

When aligning the preamplifier, the bandpass filter section must be aligned first. To accomplish this, the transistor stage must be temporarily eliminated from the circuit. An extra coax connector mounting hole (see **figs. 7** and **8)** is provided for this purpose. Install a coaxial fitting as indicated, route C6 to the fitting and align the filter as previously described. When the bandpass filter is properly aligned, transfer C6 from the extra coaxial fitting to L7 and remove the fitting from the board.

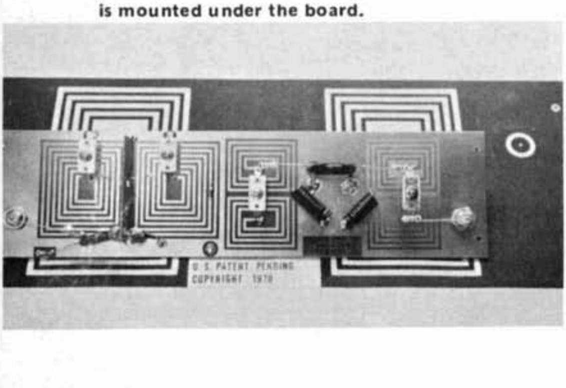
Apply voltage (9 to 12 Vdc) to the preamplifier and select R1 for 5-mA drain current. Apply an input signal – at the center frequency of the bandpass filter – and tune C8 for maximum indicated level on the receiver S-meter. Keep signal level down so the meter reads in the range from S5 to S7. With C8 peaked for maximum signal, tune C7 for maximum. C7 will tune somewhat more broadly than C8. Check the setting of C8 again, keeping the output of the rf signal source at a relatively low level.

Disconnect the filter-preamplifier and measure the output of the signal generator with your S-meter. (It is assumed that you have a 50-ohm-output signal source, or can rig one with your antenna system and a grid-dip oscillator across the yard.) Put the filter-preamplifier back in the system and measure the output level with

fig. 7. Half-size layout for the 144-MHz bandpass-filter preamplifier board.



50-MHz interdigital preamplifier. The filter section is to the right; fet preamplifier to the left. Capacitor C6 is mounted under the board.



your S-meter. There should be 10 to 15 dB additional signal level with the preamplifier; noise level, with the antenna disconnected, should be noticeably less than your present converter.

The total gain of the preamplifier is the gain of the E-300 grounded-gate stage, less bandpass-filter losses. Therefore, although the E-300 is capable of 15 dB or more gain at 50 or 144 MHz, filter losses of 1 to 2 dB reduce total package gain to 10 to 12 dB.

The grounded-gate preamplifier is unconditionally stable. The isolation between *wells* (term applied to the etched inductances on the printed-circuit board) has been measured as high as 70 dB with as little as 1/8 inch copper between wells. In commercial CATV preamplifiers, for example, I have run four cascaded fet stages with filters on a single board with no instability; with four stages voltage gain is on the order of 40 dB.

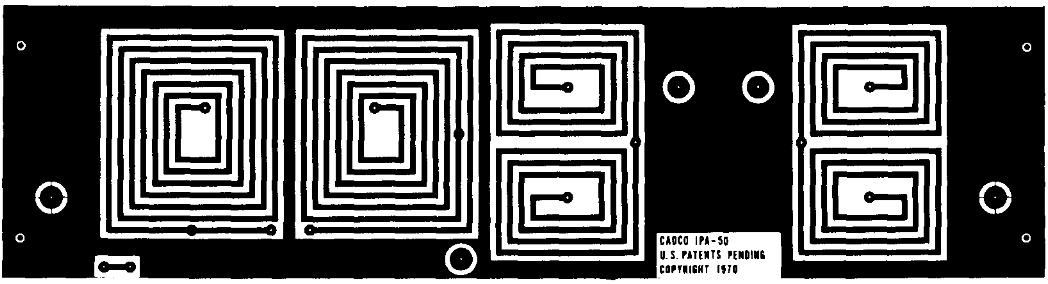


fig. 8. Half-size layout for the 50-MHz bandpass-filter preamplifier board.

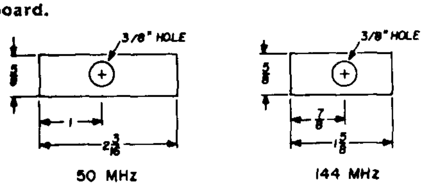


fig. 9. Layout for the E-300 mounting shields. Cut out from double-sided G10 printed-circuit board.

summary

The subject of etched inductances for vhf receiver systems has been barely scratched in this article, as I am painfully aware. Additional prototype work has been done in other areas including an etched-inductance converter (with bandpass filter), etched-inductance transmitting mixers, etched-inductance hybrid couplers, and etched-inductance stopband filters (with preamplifier) to replace repeater cavities.

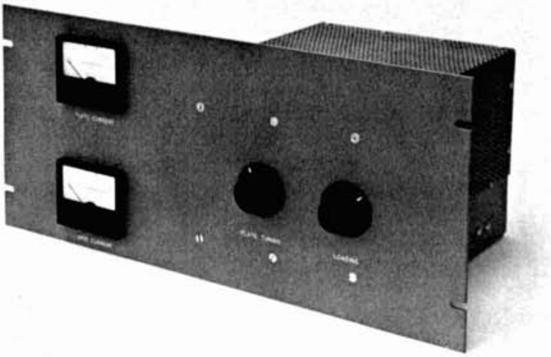
Etched-inductance circuits are relatively simple projects for the serious experimenter. Simply use 1/8-or 1/16-inch tape* to form the inductances, with 1/16 inch between inductances. Etched inductances are measured by the square well area, and a 1.25-square-inch well with 1/16-inch inductors and 1/16-inch spacing between inductors hits 144 MHz. The etched inductances can be easily tapped, and you can re-tap many times if you use a 25- or 35-watt iron and don't use sustained heat on the etched strips.

references

1. Charles Ryder, U. S. Patent number 1,837,678, "Inductance Coil — Particularly Adapted for use with Radio Tuning Devices," December 22, 1929.

2. Robert Cooper, Jr., W5KHT, "Interdigital Preamplifier and Comb-line Bandpass Filter for VHF and UHF," *ham radio,* August, 1970, page 6.

ham radio



two-kilowatt linear amplifier for six meters

This high performance six-meter linear features the new Eimac 8877 and provides excellent stability, good reliability and minimum harmonic output

Robert I. Sutherland, W6UOV, EIMAC Division of Varian, San Carlos, California 94070

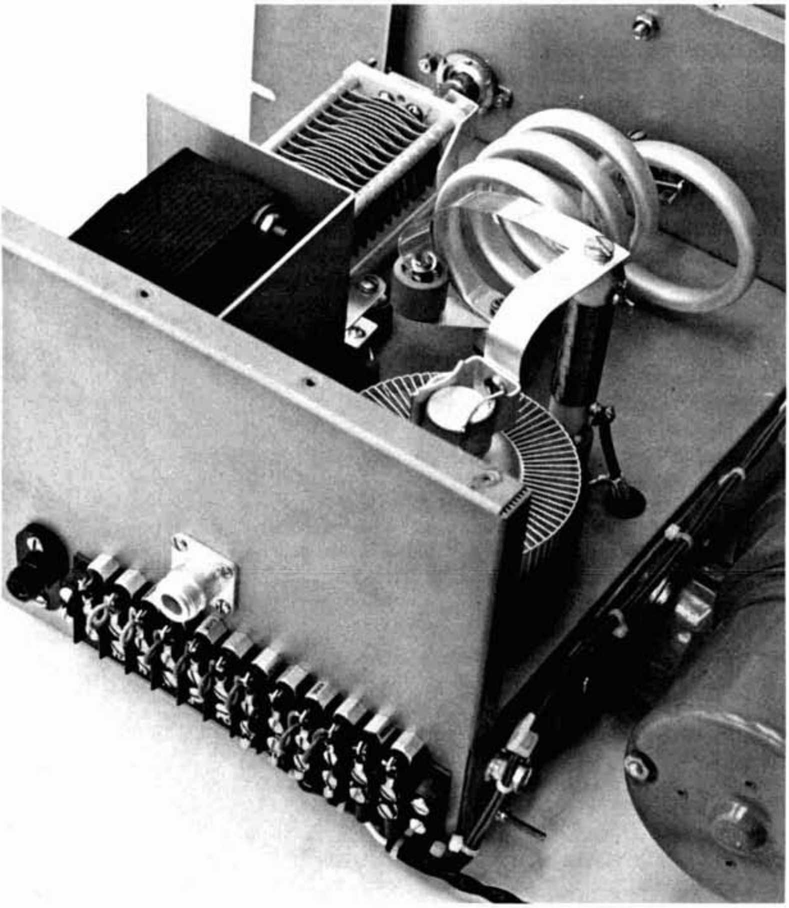
The serious six-meter operator needs a high power amplifier that will function reliably over extended periods of time and have minimum harmonic radiation. Such amplifiers seem to be commonplace for the "dc bands" but are rather rare for 50 MHz and above. Many six-meter amplifier designs are cranky, hard to neutralize or otherwise unstable or tricky to adjust.

The amplifier described in this article has none of these undesirable attributes. It will run key-down on a 24-hour basis, if need be, and is stable and easy to adjust. I have used it over a period of months and it has proven to be a valuable

The new high-mu 8877/3CX1500A7 triode recently announced by EIMAC.

adjunct to the spread of six-meter equipment in my station.

This amplifier uses a grounded-grid circuit with a new high-mu triode just announced by Eimac: the 8877/3CX1500A7. This ceramic/metal triode is intended for linear service in the high-frequency and vhf range. The amplifier is intended for the maximum legal power input, 1000 watts dc, and can develop up to 2000 watts peak envelope power input during ssb operation. The amplifier requires a driver that can supply approximately 40 watts PEP at 50 MHz. Using a plate potential of 2600 volts and plate current of 750 milliamperes, power output will be about 1200 watts. This represents an amplifier efficiency of 61% and a power gain of 14.8 dB.



Top view of the plate circuit of the linear amplifier showing the shorted-turn tuning scheme. The shorted-turn is hard-soldered to shaft coupler to allow front panel tuning. The "anti-inductance" strap can be seen connecting the top of the plate choke to the plate blocking capacitor. Note that the position of the plate blocking capacitor can be changed by loosening one screw and rotating the capacitor around the screw.

A schematic of the amplifier is shown in **fig. 1.** The control grid is operated at dc ground with a minimum of inductance between the tube and the chassis. The plate and grid currents are measured in the cathode return lead. A 12-volt 50-watt zener diode is placed in series with the cathode return lead to set the desired idling plate current. No special neutralization scheme is needed to attain completely stable operation.

The plate circuit is a standard pi-network with tube output capacitance plus stray capacitance to the cabinet forming the input capacitance of the network (30 pF). The output loading capacitor is an air variable shunted by two fixed ceramic capacitors. Amplifier tuning is accomplished by varying the inductance of the coil by adjusting the coupling between the coil and a shorted turn.

The cathode input circuit consists of a simple T-network. The network was calculated so that a 50-ohm cable from the driver would be matched to the input impedance of the 3CX1500A7 at full power. The input impedance of the tube is 54 ohms resistance in parallel with 26 pF capacitance. The match holds over the 1-MHz tuning range of the amplifier.

A 10,000-ohm 25-watt resistor in the cathode lead of the 8877/3CX1500A7 is used to reduce standby current through the tube to a low value. When the exciter is turned on, a set of contacts on the vox relay (or other control relay) shorts out the 10,000-ohm resistor, causing the tube to operate at its normal idling plate current. The 200-ohm 10-watt resistor from the negative terminal of the plate supply to ground makes certain the nega-

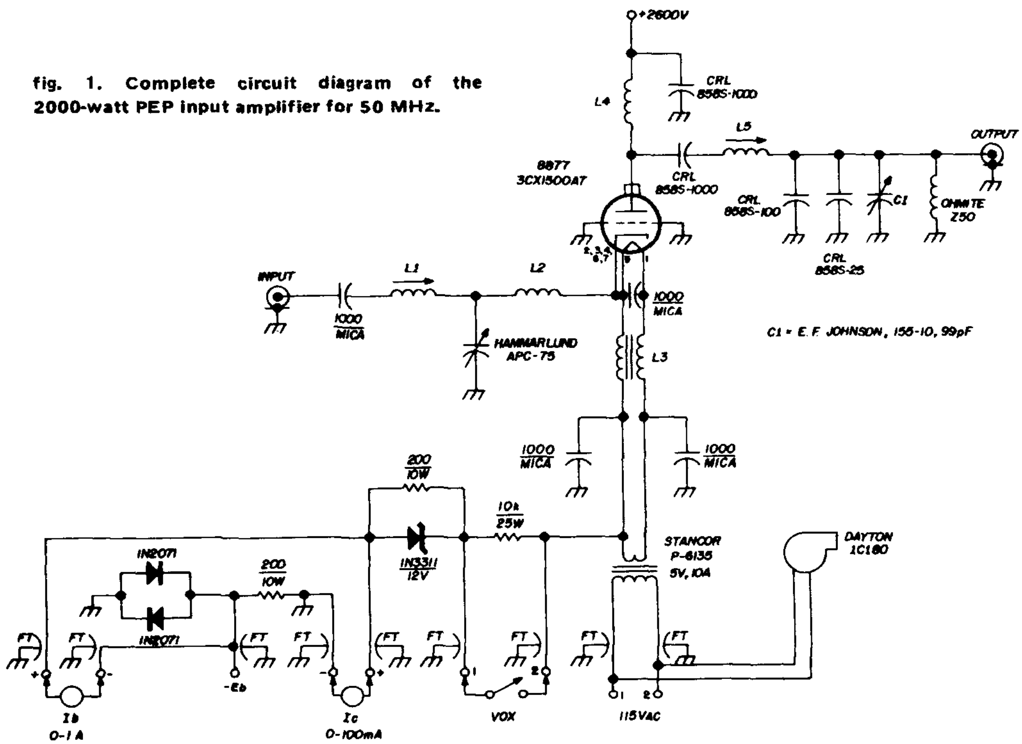


fig. 1. Complete circuit diagram of the 2000-watt PEP input amplifier for 50 MHz.

L1 6 turns no. 18 on a CTC 1538-4-3 form; coil length 7/8"

L2 6 turns no. 18, ½" diameter, 5/8" long, self-supporting

L3 Bifilar wound choke, ½" diameter core, 3" long, each coil 12 turns no. 10 Formvar; core is Indiana General CF-503

L4 54 turns no. 20 enameled on 1/2" diameter Teflon rod; winding length 1-13/16"

L5 3 turns 3/8" diameter copper tubing; inside diameter 1-7/8"; coil length 2-3/8"; shorted turn 2-¼" diameter 3/8" copper tubing ¼" from main coil

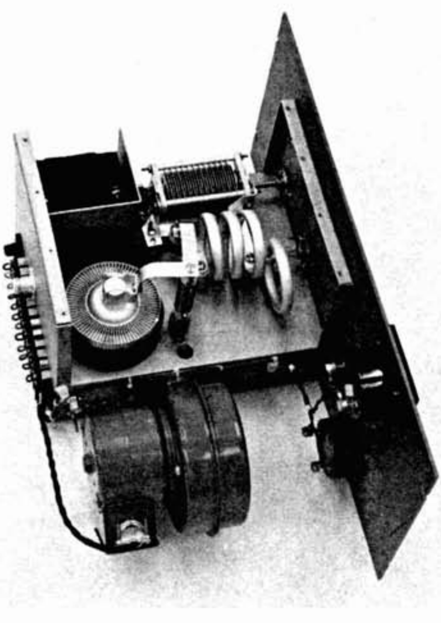
FT Erie 327 1000-pF feedthrough capacitors tive terminal does not soar to the value of the plate voltage if the positive side of the power supply is accidentally shorted to ground.

The two 1N2071 diodes across the 200-ohm resistor limit any transient surges under the shorted condition which might cause insulation breakdown. Also, these diodes afford some transient protection of the two meters by providing a path around the meters. Additional protection could be obtained by putting two back-to-front parallel connected diodes across each meter. The 200-ohm resistor around the zener provides a load for the zener and prevents the cathode voltage from becoming quite high if the zener should burn open.

the plate circuit

Top views of the amplifier chassis are shown in the photographs. The closed ring near the front panel is the shorted turn used for tuning; it is made of 3/8-inch diameter tubing, hard soldered to a brass shaft coupler with copper-silver solder. Soft solder would not be advisable in this application because of the high circulating current in the shorted turn. The "anti-inductance" strap is used to set the tank circuit to the desired tuning range. This strap runs from the top of the plate rf choke to the plate blocking capacitor. The position of the blocking capacitor can be moved to allow the strap to be flexed and set to the proper position. Note that the current through the strap is going in the opposite direction from the current in the coil at any instant and therefore causes field cancellation.

Another view of the plate circuit. The air variable across the top edge of the chassis is the adjustable part of the loading capacitor. Two ceramic barrel capacitors are mounted in parallel with the air capacitor and can be seen at the end of the variable capacitor near the filament transformer shield.



To set the amplifier to the low-frequency end of the band, the shorted turn is completely decoupled and the position of the blocking capacitor and the anode strap adjusted to resonate the plate circuit to 50 MHz. As the shorted turn is coupled tighter, the total inductance in the plate tank circuit will be reduced, causing the resonant frequency to increase. When the shorted turn is fully coupled, the resonant frequency of the plate tank circuit will be about 51 MHz.

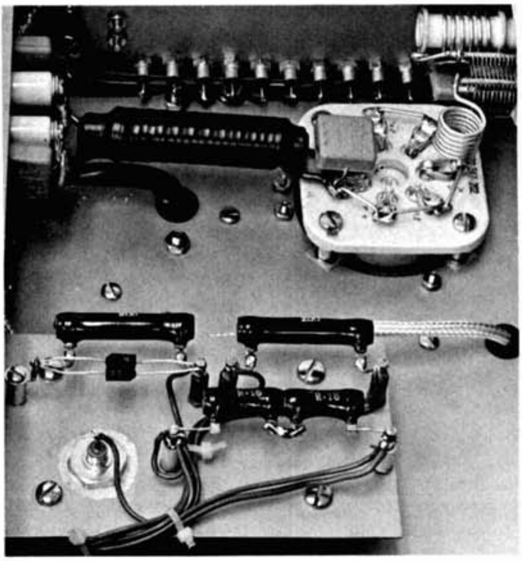
Amplifier loading is accomplished in the same manner as in a typical pi-network amplifier. The loading capacitor is the air variable along the top right edge of the chassis. The two ceramic fixed capacitors are at the left end of the air capacitor and at the end of the coaxial cable coming from the type-N coaxial receptacle mounted on the back panel.

The plate choke is made of 54 turns of no. 20 enameled wire closewound on a one-half inch diameter Teflon rod. The winding length of the coil is 1-13/16 inches. The choke is mounted on top of the ceramic capacitor which is used to by-pass the B-plus end of the choke.

Visible on the back of the front panel are the *Jackson* ball-drive assemblies. These handy devices provide a very smooth and slow "feel" to the tuning. The 5.0-volt 12-ampere filament transformer is visible inside its aluminum shield at the top left end of the chassis.

the input circuit

The input matching network is a standard T-design consisting of two series coils and one shunt capacitor. One coil and the shunt capacitor are variable. With these two adjustments it is possible to cover a wide range of impedance transformations. The controls for the variable elements are brought out the left rear side of the chassis. Once the adjustments have been made, no tuning is required over the first megahertz of the band.



View of the underside of the chassis showing the input circuit and the location of the zener diode and resistors. The T matching network is in the upper right hand side of the chassis. The heater-cathode choke is mounted between the socket and the ceramic stand-offs at the left side of the picture. Note that the socket is mounted below the chassis to allow passage of the cooling air. The straps grounding the grid to the chassis can also be seen under the threaded brass spacers used to sub-mount the socket.

The input matching network can be seen in the top right corner of the under chassis photograph. The cathode-heater rf choke is near the tube socket. The choke is bifilar wound with twelve turns on each coil using no. 10 Formvar insulated wire. The core material is *Indiana General CF-503,* one-half inch in diameter.* The core permeability is a little high for this application, but the material was available and has not given any trouble. The Johnson 122-247-202 socket is mounted one-half inch below the chassis using threaded brass spacers. Four pieces of brass shim stock, or beryllium copper, are formed into an "L" shape to mount between the brass spacers and the chassis and make contact to the control grid ring.

*Available from Newark Electronics Corporation, 500 North Pulaski Road, Chicago, Illinois 60624. Order catalog number 59F1521, $2.50 plus shipping.

the tube

The 8877/3CX1500A7 is a new ceramic triode having good division between the plate current and the grid current. It has EIA base no. E7-2 which can be used with the standard septar sockets. The tube has a plate dissipation rating of 1500 watts, and has a mu of approximately 200. The cathode is indirectly heated, and the filament requirements are 5.0 volts at 10 amperes.

performance data

Many different operating conditions were tried with this amplifier. The conditions most suitable for amateur ssb operation at 2000 watts PEP input are:

Plate voltage	2600 Vdc
Plate current (single-tone)	750 mA
Plate current (idling)	40 mA
Grid voltages	-12 Vdc
Grid current (single-tone)	58 mA
Power input	1950 W
Power output	1200 W
Efficiency (apparent)	61 %
Drive power	40 W
Power gain	14.8 dB

The intermodulation distortion products at full peak envelope power input under the above operating conditions are:

3rd order	-44 dB
5th order	-37 dB
7th order	-64 dB
9th order	-68 dB

ham radio

More Details? CHECK–OFF Page 94

speech clipping

in single-sideband equipment

Audio speech clipping produces excessive distortion when used with ssb equipment — here's why

Walter Schreuer, K1YZW, Riverbank, Ipswich, Massachusetts 01938

In the old days when ssb was unknown on the amateur bands the intelligent use of a speech clipper with a carefully designed filter frequently made contacts possible which otherwise could not have taken place. Distortion was quite bad, so much so that the readability "in the clear" was actually degraded slightly, but you could — and did — switch the device out of circuit when conditions were good. Unfortunately, when you try to use the same simple technique with ssb the results are disappointing, often atrocious. Many amateurs have even abandoned the scheme.

Too much confusion still exists regarding speech processors. For example, a completely illogical comment in a well-known British magazine recommended speech clipping to avoid overdriving the transmitter output stage while recognizing that the process is deficient in other respects. I recall the outburst of an exasperated ham who received consistent adverse reports on his $15 transistor clipper: "It must work – you can't be listening right!"

Actually, there are several references that point out the incompatibility of speech clipping with the ssb. An early edition of the SSB Handbook (put out by Collins Radio) is quite outspoken on the subject. The following is an attempt to shed some light on the matter in simple terms, at the risk of over-simplification, and to briefly examine some preferable alternatives.

some basic facts

The human voice has a low average-to-peak power ratio; our transmitting apparatus is limited primarily to a specific peak power level. If this power is exceeded, the result is excessive distortion and bandwidth, among other possible effects. In a-m and fm systems the situation can be improved, at the expense of fidelity, by instantaneously peak limiting or clipping the audio frequency signal prior to the modulation process. Considerable harmonic and intermodulation distortion products are generated by the clipper which can greatly increase the bandwidth of the signal. For this reason the clipper is always followed by a low-pass filter designed to cut off at 3kHz or so. To a small extent this filter negates the action of the clipper, but even so, effective gains of 10 dB or higher can be obtained. (Please note this applies to a-m and fm, *not* ssb.)

It may seem strange to talk about gain in connection with devices intended to

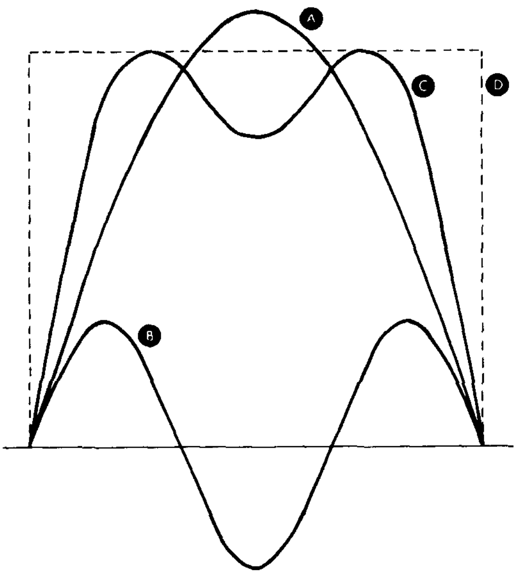


fig. 1. The derivation of a square wave. The fundamental component is shown in A. B is the third harmonic. The sum of A and B is shown in C. D is the resultant with higher odd harmonics of proper amplitude and phase.

improve readability without increasing the peak power output. However, the definition is quite simple: the gain is the ratio of the peak power of an unprocessed transmission to that of a processed one, where the former produces the same readability as the latter at the distant receiver under very poor conditions.

We also talk about the amount of clipping in decibels. This is simply a measure of the reduction of the largest speech peaks, or more precisely, the ratio of the gains of the audio amplifiers with and without clipping for the same peak power output. In a-m or fm links 15 dB clipping can result in gains of 9 to 12 dB. This produces the same readability at the distant end, under poor conditions, as an unclipped transmission with 8 to 16 times peak power.

phase relations

When you severely clip a sine wave or single-tone signal, the resultant approximates a square wave. This can be thought of as the combination of another sine wave and its odd harmonics. The latter have definite relationship to the fundamental frequency component in both amplitude and phase. **Fig. 1** shows a sine wave **(fig. 1A)**, a third harmonic component **(fig. 1B)** and their resultant **(fig. 1C)**. If you add more odd multiples in proper amplitude and phase you eventually end up with a square wave **(fig. 1D)**.

If the phase of the harmonic signals is shifted so that their peak amplitudes add to that of fundamental tone the results would be as in **fig. 2**. The peak amplitude of the resultant ***(fig. 2D)*** *is more than* twice (8 dB greater) the square wave of **fig. 1**. If the peak amplitudes of all the harmonics subtract from the fundamental the dip in the middle of the resultant waveform would approach zero! These examples of extreme cases of phase shift emphasize their importance.

ssb generation

In an ssb exciter the phases of the individual components of the audio signal are not maintained. The balanced modulator does no harm in this regard. The *resultant* amplitude of the upper and lower sidebands forming the dsb signal remains peak limited in a properly designed and adjusted circuit with clipped audio input. (One point in favor of dsb is that speech slipping *can* be used.) However, as soon as one sideband is removed the delicate balance of the component signals is upset, resulting in severe amplitude variations. You are left with a set of rf components which correspond in amplitude and frequency to the audio fundamental, its harmonics generated by the clipping action. At rf these component signals are not harmonically related, and with the carrier and opposite sideband removed add up arithmetically to form the composite signal. Periodically the rf envelope exhibits maxima and minima with magnitudes dependent upon modulating frequency and system bandwidth.

As a practical example, assume that we have a heavily clipped (approximately square) 400-Hz wave of 0.8 volt amplitude and use it to produce a 100-kHz ssb signal. Also assume that conversion gain is unity. **Table 1** shows the frequency components of the ssb signal and their amplitudes. Components corresponding to harmonics above the seventh are ignored since they are attenuated by the filter following the clipper. Periodically, all the peaks will coincide, resulting in a maximum of the rf envelope that is equal to the sum of the individual peak values. There will also be times when the peaks of each of the distortion components will coincide to subtract from the amplitude of the main component and give a minimum value of the envelope. In **table 1** it is shown that the amplitude of the resultant envelope will vary 14 dB at an audio rate,* though a constant input signal is used! This is exactly the reverse of the desired effect. Bear in mind that this extraneous amplitude modulation is quite independent of any variation of the input signal. While the 14 dB variation (rather less at higher audio frequencies) is probably less than the normal variation in a speaker's voice the accompanying distortion often offsets any small numerical gain in average power.

phasing-type exciters

The situation, as described so far, is directly applicable to phasing exciters. If you severely limit the low-frequency response below 1000 Hz in the speech amplifier so the low notes are clipped only lightly, some gain in average power output can be obtained, together with noticeable distortion and obvious lack of bass. I do not believe that any gain realized through speech clipping in this manner is any greater than that obtainable with a properly designed alc or volume compressor system. The latter of course produce negligible distortion and can be designed to give properly balanced frequency response.

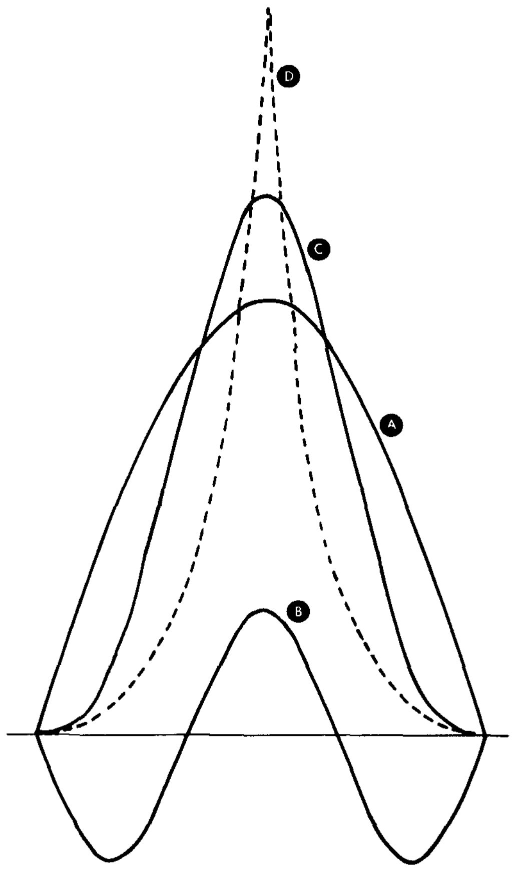


fig. 2. The affect of improper phasing of components. A is the fundamental; B is the third harmonic; C is the sum of A and B; D is the resultant.

filter-type exciters

The effects of speech clipping in ssb exciters are small compared to the further deterioration caused by the filters used in most modern equipment. The difficulty is the "transient" response of these filters,

*It can be shown that the amplitude modulation frequency is 800 Hz, or more generally, twice that of the input speech signal.

or the response to impulses or very rapidly changing rf envelopes. The effect is the same as that observed in receivers when impulse interference is present. Under those conditions you are often better off to switch out the ssb filter if no adjacent-channel interference is experienced.

A rapid change in the rf envelope causes the filter to give out a high amplitude spike followed by several cycles of damped oscillations. The initial spike is probably inaudible in your receiver because of its short duration. However, subsequent cycles constitute what is known as filter ringing. The amplitude of the spike, the ringing frequency and amplitude are a function of the filter; The effect worsens as the filter cut-off characteristic is improved.

table 1. Results when a severely clipped 400-Hz wave, amplitude 0.8, is used to produce a 100-kHz ssb signal.

	relative amplitude	af parameters	rf parameters
fundamental	1.00	400 Hz	100.4 kHz
3rd harmonic	0.33	1200 Hz	101.2 kHz
5th harmonic	0.20	2000 Hz	102.0 kHz
7th harmonic	0.14	2800 Hz	102.8 kHz
sum of distortion terms		na*	0.67
maximum amplitude		0.8	1.67
minimum amplitude		0.8	0.33
variation		0 dB	14 dB

*not applicable because of harmonic relationship

In ssb exciters appreciable speech clipping produces the same effect though some relief is afforded by the audio filter following the clipper. The ringing frequency is independent of the audio input to the exciter and represents additional and particularly vicious distortion. The initial spike can have a larger relative amplitude than the audio input which causes it, thereby requiring a reduction in audio gain below that which would have been used without the clipping device. In most cases the operator is unaware of this since his alc takes care of the problem; he finds it hard to believe that his audio is not only badly distorted but is often weaker than without the clipper!

I recall one case several years ago where the builder of a clipper reported that the only way he could make his gadget work properly was by pulling the alc rectifier tube in his Collins S-line. I am sure his ham neighbors must have objected in no uncertain terms; his results would have been less obnoxious if he had just removed the tube and omitted the clipper!

A practical demonstration of the nasty things I have described is not at all difficult. All it takes is an oscilloscope for viewing the envelope of the output of the transmitter and an audio square wave generator for the microphone input and for the sync input of the scope. The effects are best seen with a low frequency input between 300 and 500 Hz. Also instructive are the results obtained with a very low frequency input of 100 to 200 Hz, when only the harmonics can pass through the ssb filter. The output will resemble that of a badly distorted and overmodulated a-m wave. This demonstrates the absolute necessity for severe low-frequency filtering if a speech clipper must be used.

To conclude, speech clipping in any form is *incompatible* with the ssb mode as we know it. The generation of appreciable harmonics of the audio signal is the source of the trouble. Therefore, we must include as undesirable the many variations which produce the same effect: logarithmic limiters, instantaneous compressors, including those built into phone patches. I cannot recall all the names that have been used to describe essentially similar devices. They will do a good job on a-m or fm but not with ssb. Now let's stop being completely negative and take a look at schemes which can do a good or fair job of raising your talk power.

automatic level control

Basically, alc is intended to serve the same purpose as automatic gain control in receivers. One of the expressions must be a misnomer; the purpose in both cases is to obtain constant peak signal output by controlling the gain of a preceding amplifying stage. A typical system is shown in **fig. 3.** When the peak rf signal exceeds the delay voltage the excess voltage appears across resistor R1. The rf is removed by a filter (R2 and C2) and the resulting dc voltage is used to reduce the gain of a preceding stage (preferably a stage operating at a different frequency in the interest of stability). The gain between the controlled stage and the sampling point should be large so that the actual peak rf level will exceed the delay voltage only slightly.

The attack time is largely determined by the product of R2 and C2, the charge constant. The charge time constant should be short so the duration of the initial rf peaks is brief and the resulting overmodulation (flat-topping) is of little consequence. Those familiar with servo loops will realize that the attack time cannot be made too short or control overshoot followed by damped low frequency oscillations will take place. In practice there is no difficulty in obtaining a satisfactory compromise.

The decay or recovery time of the system depends on the product of C2 and (R1 + R2), the discharge time constant. Note that R1 does not affect the attack time; therefore, it may be selected to determine the recovery time only. If recovery time is long — several seconds — the output amplitude faithfully follows variations in the input signal with the output peak level nearly constant and equal to the delay voltage. Under this condition, which is typical of receiver agc circuits, no gain in average power is obtained. However, the benefits are considerable since the operator doesn't have to worry about overdriving the output stage. This can result in appreciable *psychological* gain.

If the alc recovery time is made very short — less than 50 mS or so — it becomes comparable to the periods of the lower audio frequencies and will result in distortion similar to flat-topping. A medium time constant — between 1/8 and 1/2 seconds — will avoid this and at the same time be low enough to compensate for the slow or syllabic amplitude variations of the human voice. This makes your voice sound a little unnatural, but no distortion nor increase in bandwidth will occur. The average power gain obtained by smoothing out the syllabic variations is between 3 and 6 dB in a well designed system and depends upon the operator's voice characteristics.

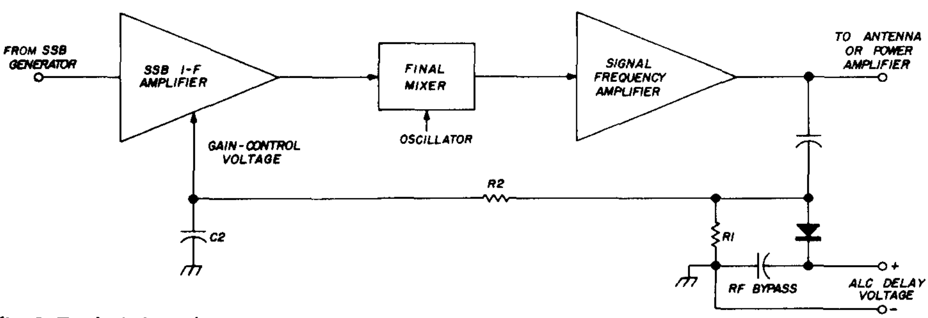


fig. 3. Typical alc system.

Alc is now a standard feature in modern ssb transmitters. Unfortunately, in many equipment its performance leaves a lot to be desired. In these cases alc is best regarded as an emergency brake and its extensive use is to be avoided. On the other hand, I know of one transmitter — and I am sure there are others — with excellent alc performance. All the operator has to do is turn up the audio i-f level to obtain an essentially distortionless lift in average power.

It is not my purpose to enumerate the many dubious practices and glaring design errors I have noticed in some commercial amateur equipment. I once had to redesign and rebuild the alc circuitry in an exciter of well known manufacture before I was able to operate on the same band as its owner two miles away. His equipment was brand new and was functioning as designed but the signal was little better than it would have been when overmodulated without alc.

volume compression

Volume compression can be regarded as an agc system operating at audio. The performance is the same as a properly functioning alc system. In this case, too short a discharge time will result in speech clipping with its deleterious effects. A medium time constant (about ¼ second) will give an appreciable lift in average power.

If a volume compressor is used with a good alc system it will result in duplication with virtually no additional advantage. On the other hand, a good volume compressor is a considerable asset when used with exciters containing poor alc circuitry, or none at all.

rf clipping

Although rf clipping has come into prominence only recently it is an old idea. I have references which go back to 1952, and there is a patent dated 1926 for a similar process! Rf or i-f clipping will do for ssb what speech clipping does for a-m and fm, as well as quite a bit more. However, cost is rather high, and retrofitting older equipment is likely to be difficult.

As I have attempted to explain, the incompatibility of speech clipping and ssb stems from the audio frequency harmonics which are generated within the speech bandwidth. If the clipping process is postponed until after generation of the ssb signal the harmonics will be multiples of the intermediate or radio frequency and are nowhere near the fundamental. Their removal is no problem whatsoever, and you have a clipping process which is free from harmonic distortion. This is appreciably better than results with ordinary speech clipping in a-m or fm.

Unfortunately, there are intermodulation (IM) products: beat frequencies (sum or difference) when two or more signals exist simultaneously within the passband. Higher order IM products are the beat frequencies of the *harmonics* of the signals and these can fall in or near the fundamental signal band. The amplitudes of these IM products are fairly small as is their effect on signal quality. However, they may increase the bandwidth of the signal beyond acceptable limits. Therefore, a ssb filter is required after the rf or i-f clipper.

Fig. 4 shows a clipping arrangement operating at the first ssb frequency. The ssb generator is conventional, except that in a new design the first filter need only have moderate performance, say 20 dB sideband rejection and less carrier suppression assuming a good balanced modulator. The second ssb filter will determine

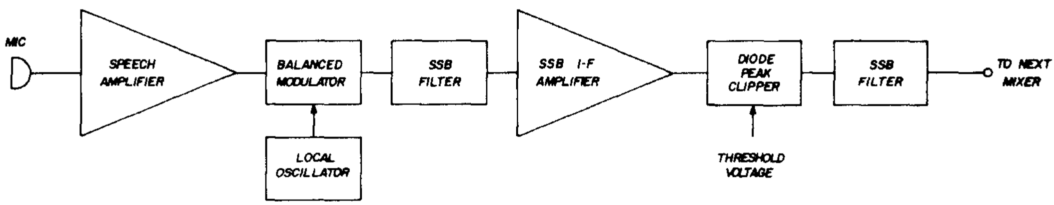


fig. 4. Single-sideband generation with rf clipping.

the quality of the outgoing signal and should have sharp skirts and a high attenuation floor. The agreement in the cut-off frequencies of the two filters must be very close on the carrier side (both sides if the same filters are used in a selectable sideband exciter). No overloading must occur in the stages preceding the i-f clipper. These requirements make modification of an existing exciter a difficult job.

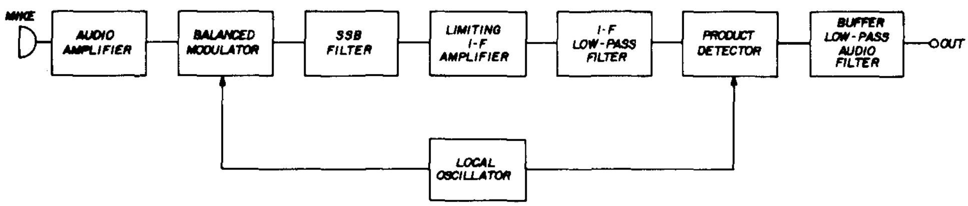


fig. 5. Block diagram of the Comdel CSP-11, an audio accessory unit with rf clipping.

Rf clipping is at least as good as speech clipping with a-m with the advantage that distortion is small compared with the older method. A 10-dB gain in average power can be expected with 15-dB clipping. The actual gains may be lower or higher depending on the severity and nature of the difficulty of the communication path. In 1961, Paul Day, W1PYM, and I demonstrated and recorded the effectiveness of rf clipping by simulating a poor ssb link. An unprocessed transmission was adjusted to be on the threshold of readability, say R2. A transmission with the identical peak output power and incorporating speech clipping produced no improvement. In contrast, a transmission using rf clipping produced a readability of 4 to 5. In fact, the peak output could be reduced considerably below that of the unprocessed transmission before intelligibility was affected.

compatible audio accessory unit

Rf clipping is probably the most effective way to increase the talk power of a ssb transmitter. Since modifying an exciter to incorporate the feature is difficult at best, a way around the problem is to build a closed-loop ssb system with rf clipping. The output will be at the original audio frequency with instantaneous amplitude limiting, just as in a speech clipper, but without any new harmonic components. Therefore, it is suitable for the speech input of a ssb transmitter (and will give superior performance when used with a-m and fm equipment).

Fig. 5 shows the block diagram of such an accessory unit, the Comdel CSP-11. Note that there can be no frequency error since the same oscillator is used for modulation and demodulation. In this unit peaks are limited or clipped instantaneously, there is no discharge time constant, and harmonic distortion is absent.

While experimenting with rf clipping the scheme shown in **fig. 5** was realized and tested. There was no audibly discernible difference between the performance with rf clipping and that obtained with the audio accessory unit. (In theory, the latter should produce slightly higher IM distortion.) The audio was demonstrated to a member of a well known audio consultant firm; his first reaction was disbelief that he was listening to a clipping system! His own tests with the processed audio (there was no rf link involved) showed that:

1. When mixed with noise, the new method is slightly superior to normal speech clipping; 15 dB clipping produced 10 dB intelligibility gain with no apparent distortion (in noise).

2. There was no loss of intelligibility whatever "in the quiet" up to 24 dB clipping. In regular speech clipping systems where there is some loss because of distortion.

Many years of experience have convinced me of the value of rf clipping in the simulated form. Unless specifically requested for demonstration purposes I never switch the device out of circuit and often receive unsolicited gratifying reports.

conclusion

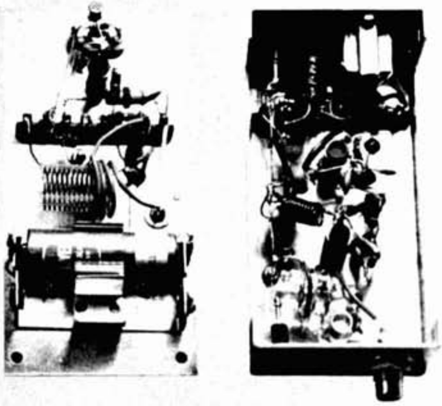
Speech clipping in its old form, or any device which causes severe distortion of the audio signal, should not be used with ssb transmitters. Properly designed alc systems and volume compressors can be used to prevent flat-topping and give moderate gain in talk power. With regard to talk power, rf clipping and its audio derivative will give the best results, but the devices are rather costly.

Like most things in life, processing the ssb signal can be overdone and the most effective devices misused. For instance, moderation is in order when the microphone is in a noisy location. Most of us are familiar with the "aeronautical mobile" effect where the noise power is as high as that of the intelligence whenever the operator stops speaking. While the signal-to-noise ratio is not actually degraded the effect on the listener is one of annoyance. It is well to ensure that the PEP output of a transmitter with speech is at least 15 dB – preferably 20 dB – above the noise PEP.

I hope that I have managed to convince you that speech clipping is *not* for the ssb station. There are other devices and techniques available, though they cost a bit more. When viewed against the total amateur station investment the additional expense is really quite reasonable.

For those of you who want the ultimate in performance (and cost) a local long-time-constant agc loop ahead of the rf clipper will ensure that a fixed amount of clipping, say 18 dB, can never be exceeded. A properly adjusted volume compressor can be made to serve the same purpose.

ham radio



field-effect transistor transmitters

Low-power transmitters for two and ten meters that use field-effect transistors in every stage

Albert D. Helfrick, K2BLA, Paramus, New Jersey 07652

The field-effect transistor has recently been finding its place in radio communications equipment. Although its performance as an rf amplifier and mixer is well known the fet's merit in other functions seems to have gone unnoticed. The fet can function well in dc amplifiers, audio amplifiers, switching circuits, oscillators, multipliers and phase modulators. This article presents a low-powered vhf transmitter that uses field-effect transistors in every stage.

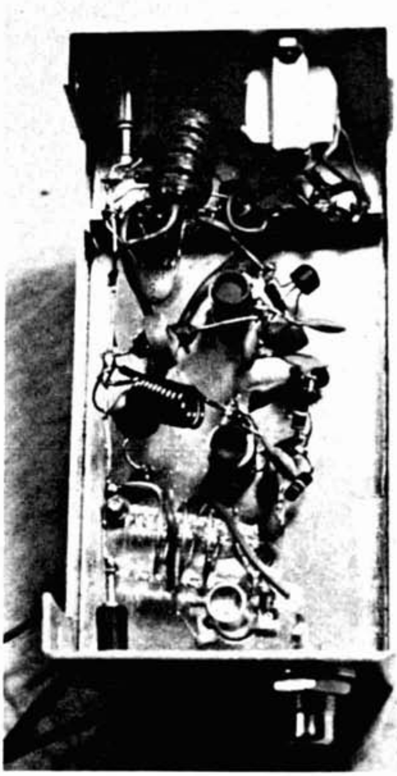
Although the fet deserves consideration when designing vhf transmitters it will not quell the nightmares of the solid-state vhf transmitter designer. It has its advantages: inexpensive, simple class-C biasing, low feedback capacitance, good efficiency with a 12-volt supply and relatively high power gain. The fet also has its disadvantage – low power dissipation. Commercially available field-effect transistors were developed primarily for small-signal use and typical power dissipation ratings are on the order of 0.4 watt. Since these ratings are based on no external heat sinking it is possible to decrease the case temperature and operate the fet beyond published ratings. However, for low-powered transmitters or low-power stages of higher powered transmitters, field-effect transistors can be used as is.

I have tried several experiments with transmitting circuits using fets, including fundamental and overtone crystal oscillators, frequency multipliers, rf amplifiers, and phase modulators. The two transmitters described here use experimental circuits. Both n-channel junction fets and n-channel depletion-mode mosfets were used. Mosfets and jfets are usually interchangeable but in most cases the simplicity of gate-leak bias for class-C circuits favors the jfet. The same results can be obtained by adding a diode from gate to source in the mosfet. In most cases performance is sufficient and the use of a mosfet doesn't warrant the additional component.

two-meter fm transmitter

The two-meter fm transmitter in **fig. 1** uses five junction field-effect transistors. It is intended to be used with a portable vhf receiver as an fm walkie-talkie. Using a Heathkit GR88 vhf monitor receiver (tuned below its normal range) a range of over one-half mile was obtained between two walkie-talkies. An additional amplifier, tube or transistor, could be added for additional power for more serious work.

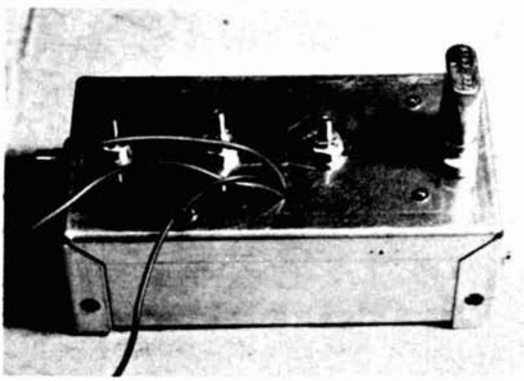
The cost of the fet transmitter is quite low. Homemade coils and chokes were used along with bargain-variety transistors. Devices were selected for optimum



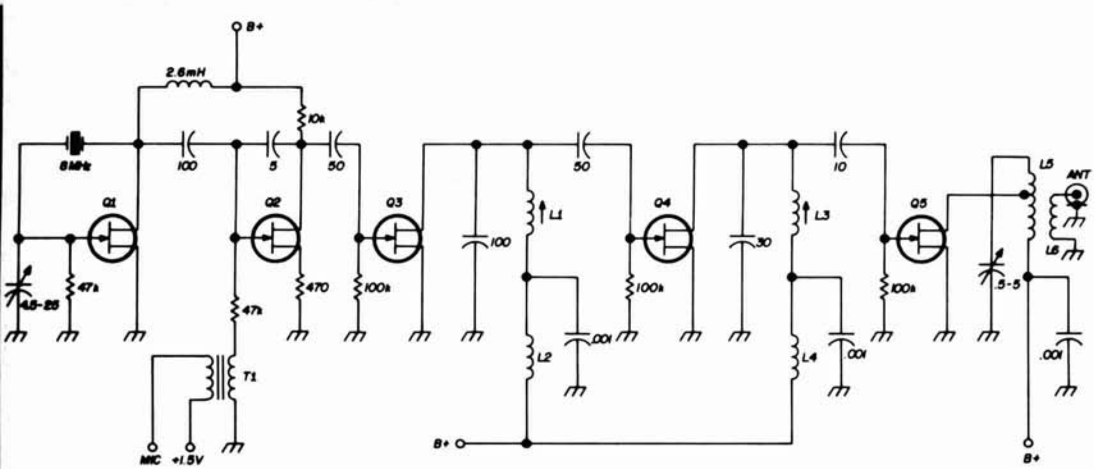
Bottom view of the two-meter fet transmitter shows component layout.

performance in the 72-MHz tripler and the 144-MHz doubler stages. Excluding the crystal the total cost was below $10.00.

Two-meter fet fm transmitter.



In this transmitter Q1 operates as an 8-MHz Pierce crystal oscillator which drives the phase modulator. The phase modulator was designed after a circuit used in an antique Link high-band mobile transmitter. The Link modulator provided 20-kHz deviation at 144 MHz using a 3.0-MHz crystal. I had no difficulty obtaining 5-kHz deviation from an 8-MHz crystal in the fet version. The modulator drives a single tripler tuned to 24 MHz,



L1 9 turns no. 28, closewound on a ¼" slug-tuned coil form

L2 0.75 μH (J. W. Miller 4651)

L3 3½ turns no. 20, closewound on a ½" slug-tuned coil form

L4 10 turns no. 20, ¼" diameter

L5 3 turns no. 18, ½" diameter, 6 turns per inch, tapped at 2 turns (Air-Dux 406T)

L6 1 turn hook-up wire around cold end of L5

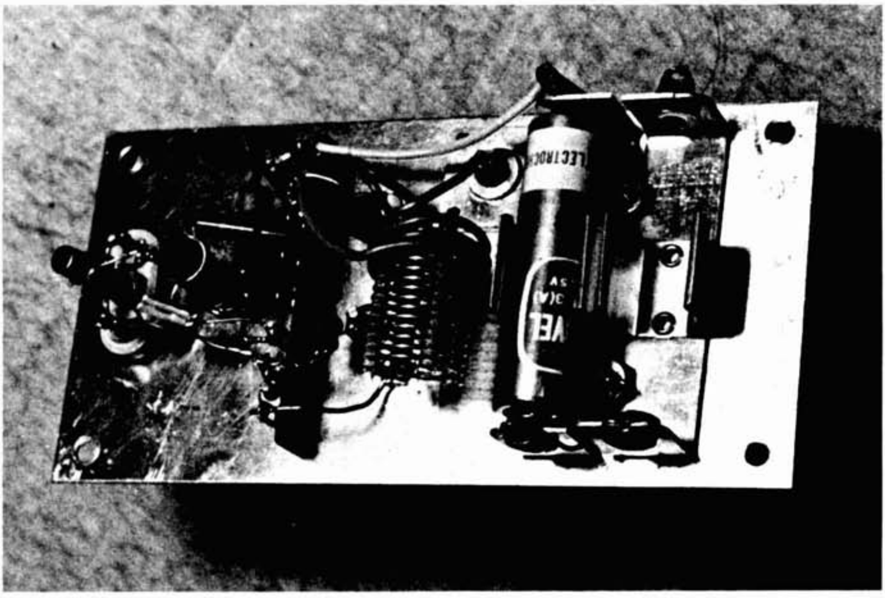
T1 Carbon-mic to grid transformer

fig. 1. Schematic diagram of the two-meter fet phase-modulated fm transmitter.

which drives another single-tuned tripler and a doubler. The efficiency of the higher frequency multipliers decreases with increasing frequency, and it was necessary to select fets for optimum performance. Since the single-tuned multipliers offer little rejection of unwanted harmonics it is desireable to double tune the 144-MHz doubler if the unit is to drive a higher powered amplifier.

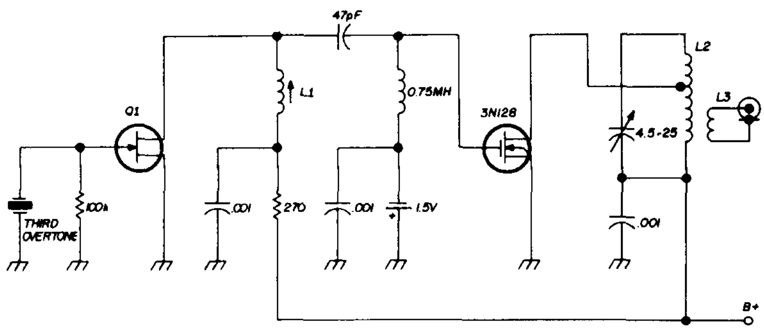
The transmitter was originally designed for a 9-volt power supply to conform with the monitor receiver. However, fet multipliers, like their vacuum-tube counterparts, require the highest supply voltage permissable for maximum

Ten-meter transmitter features a mosfet in the power-amplifier stage. The battery provides bias only, and could be replaced with a miniature mercury type.



efficiency. The fets used in the transmitter had a maximum V_{ds} of 20 volts and, as expected, best operation was obtained with a supply voltage of 20 volts. Two

The final amplifier in the ten-meter transmitter uses a single 3N128 mosfet with a 1.5-V dry cell for fixed bias. Since the drain on the bias battery is essentially



L1 12 turns no. 36, closewound on ¼" slug-tuned coil form

L2 13 turns no. 18, tapped at 8 turns (Air-Dux 408T)

L3 3 turns hookup wire around cold end of L2

fig. 2. Ten-meter transmitter using a mosfet power-amplifier stage. Power output is about 200mW.

9-volt batteries in series were used for portable operation; 9 volts for the receiver and 18 for the transmitter. A small dry cell was used for the carbon microphone.

ten-meter transmitter

The transmitter in **fig. 2** is capable of 200 mW output into a 50-ohm load at 29 MHz with an overall efficiency of 50%.* The transmitter is a two-stage affair consisting of a jfet overtone oscillator and a class-C mosfet amplifier.

I have had great success with fet crystal and self-excited oscillators. Not one fet oscillator failed to oscillate, and all the experimental circuits exhibited excellent frequency stability. In the tuned drain-oscillator in the ten-meter transmitter it was possible to operate fundamental crystals in the third overtone, and to operate overtone crystals in the fundamental simply by changing the tank resonance.

*Overall efficiency is the total transmitter power input divided into the output power. This includes the power for the oscillator.

zero, a small 1.4-volt button-type mercury cell could be used since its shelf life is several years.

Two fets were tried in parallel with a small increase in power output but a reduction in efficiency. Previous experiments with parallel mosfet amplifiers at 50 MHz showed some hope, but most circuits, when pushed beyond one-watt output, resulted in burned out mosfets. Because of the difference in mosfet characteristics, one transistor does all the work while additional parallel devices only decrease efficiency. The single 3N128 required no neutralization and provided almost 200 mW output with a 12-volt supply.

The purpose of the ten-meter transmitter is the same as that of the two-meter fm unit. Many inexpensive 30- to 50-MHz monitor receivers can easily be tuned to 29 MHz, converted to a-m, and used with the fet transmitter. From my experience with 100-mW citizens-band transceivers on 10 meters, the range of such a combination should be quite respectable.

ham radio

improving the Motorola P-33 series

Add these modifications and you'll have a truly high-performance 2-meter rig

Richard Zach, WB2AEB, 22 Pike Place, RFD-4, Mahopac, New York 10541

Some authors have referred to fm equipment as the "new surplus."[1] If you were to choose the ARC-5 equivalent of the new surplus, it would no doubt be the Motorola P-33. This is a 5-watt unit with a partially or fully transistorized receiver (P-33A or B respectively).

The P-33 transmitter uses quick-heating tubes. Power can be supplied by nicad batteries, dry cells, or a 6/12-volt power supply. The P-33 is readily available, usually at less than $100.00. In this part of the country it seems as though every ham on fm uses one.

The P-33 has two relatives. One is the H-23A (or B), which is a one-watt handy-talky. Its big brother, the D-33A (or B) Dispatcher, is a 10-watt motorcycle unit. These rigs have essentially the same transmitter and receiver strips, so the following modifications are applicable to all three models. Included are:

1. Changes for receiver 2-meter operation and an fet front end.

2. Changes to receiver and transmitter to increase bandwidth.

3. Improvements to the nicad-battery supply in the P-33BAM equipment.

receiver front end

The fet addition to the receiver was introduced to me by Walt Fairbrother, W1RYL. In one of my earlier articles, I vaguely mentioned this modification, and both Walt and I were deluged with mail inquiries. Since then I've made a few minor improvements.

The P-33 series was originally in two forms, low high-band (136-150 MHz) and high high-band (150-174 MHz). Most available units are of the high-frequency version. The following modification will improve sensitivity and also put the unit in the two-meter band. For exact pin locations and tune-up instructions, consult the manual for your unit. The receiver modifications are shown in **fig. 1.**

1. Remove the input coax cable at L1 pin 4.

2. Remove the jumper between L1 pin 2 and L2 pin 3.

3. Carefully remove the shield can from L1 by unsoldering the two lugs that hold it to the PC board.

4. Remove C1 (9 pF), C2 (47 pF), and C3 (.51 pF).

5. Disconnect the grounded end of L1 from the board.

6. Carefully drill out the pin-1 hole where the grounded end of L1 was connected. Start with a no. 60 drill to make a pilot hole. Enlarge the hole further, using a no. 51 drill. Be careful not to allow metal chips to fall into the transmitter section.

7. Using a razor blade, cut out and peel off the conductive material on the bottom of L1 (see **fig. 2**). Do this to both sides of the PC board. This will insulate pin 1.

8. Using a no. 27 drill, slightly countersink both sides of the hole.

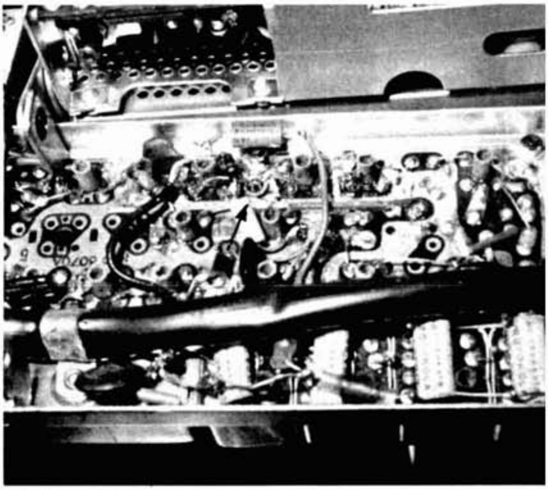
9. Insert the new C2 (56 pF) into holes 1 and 4 of L1.

10. Insert the cold end of L1 coil into hole 1.

11. Insert the new C1 (12 pF) into holes 3 and 4 of L1.

12. Solder L1 pins 1, 3, and 4.

13. Drill a pilot hole for the 3N128 between L1 and L2.



Bottom of receiver board showing the fet leads and other wiring changes. C54 can be seen near cable clamp (see receiver widebanding).

Motorola P-33 portable with homebrew battery charger. Using the jack on the side of the unit, it can be powered by an external 12 Vdc source.

14. Using successively larger drills, enlarge the hole so that the transistor case fits snugly. You should end up using a no. 12 drill.

15. Remove the can from L2 as in step 3 and remove C4 (6.6 pF). Replace it with the 9 pF capacitor (C1) removed in step 4.

16. Remove the can from L3 and remove C6 (5 pF).

17. Replace this capacitor with the 6.6 pF unit (C4).

18. Solder the shield cans onto L1, L2, and L3.

19. Install a .001 μF capacitor between L1 pin 1 and ground.

20. Install a 200-ohm, 1/8-watt resistor between L1 pin 1 and the (now vacant) pin 2. (Pin 2 will become a tie-point.)

21. Connect a small .001 μF capacitor between L1 pin 2 and ground.

22. Insert the transistor into the hole between L1 and L2. The leads should face away from the case. *Do not* remove the static discharge wire from the transistor at this time.

23. Ground pin 4 of the transistor.

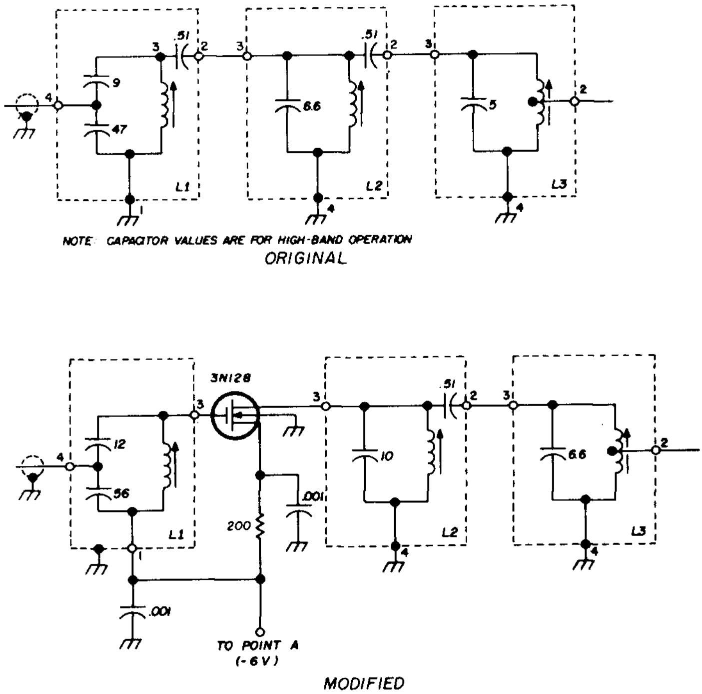


fig. 1. P-33 receiver front-end modifications per W1RYL. Before and after circuits are shown in A and B.

table 1. Accessories for the P-33 available from Motorola.*

Item	Part No.	Price
NB Permakay filter	NFN 6000 AS	$21.00
WB Permakay filter	NFN 6000 AW	21.00
Tuning tool	66A847036	1.15
Tube	type 6397	7.84
Manual for:	68P81005A40-E	1.50
P-33BAM		
P-33BAC		
H-23BAM		
H-23BAC		

*1875 Greenleaf Avenue, Elk Grove Village, Illinois 60007.

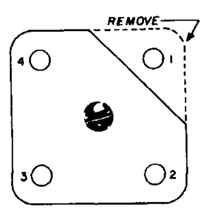


fig. 2. Conductive material must be removed as shown from both sides of the PC board under coil L1 for receiver front-end mods.

24. Connect lead 3 of the transistor to L1 *pin* 3.

25. Connect transistor lead 2 to L1 pin 2.

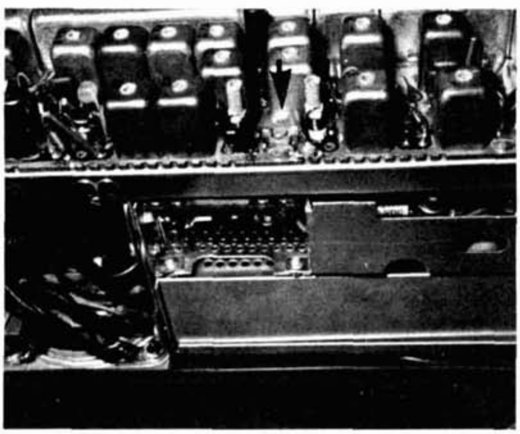
26. Connect transistor lead 1 to L2 pin 3.

27. Run a wire from L1 pin 1 to point A (see **fig. 1**). (Point A is between L11 and L9.)

28. Connect the inside conductor of the antenna coax cable to L1 pin 4 and ground the shield.

29. Remove the static-discharge wire from the transistor.

30. Retune the front end as described in the manual.



Top of receiver board showing L1 and L2 without cans. The top of the fet can be seen between the coils just above the screw.

increasing bandwidth

If you don't know whether your receiver is wide or narrow band, look for a long, thin Permakay filter in the receiver section. If the receiver is a wideband unit, *the filter will be numbered* NFN 6000 AW. Narrowband receivers will have the number NFN 6000 AS.

If narrowband operation is used in your area, you'll be delighted to know that most P-33s are narrowband. However, if your area uses the more common wideband deviation, start warming up the soldering iron.

table 2. Capacitors to be added to the P-33 transmitter. (All are 500 Vdcw.)

Capacitance (pF)	Connections
8.2	V3 pin 1 to ground
8.2	V4 pin 4 to ground
2.0	V5 pin 1 to ground
1.5 20%	across L8
1.5 20%	from one side of L9 to L9 center tap
1.5 20%	from other side of L9 to L9 center tap
1.5 20%	across L10

1. Remove C54. This is a 2000-pF capacitor at the output of the Permakay *filter. It's located very close to the* clamp that secures the control cable.

2. Connect a small 56k resistor between L30 discriminator can pin 10 and pin 6.

3. Connect another small 56k resistor between pins 8 and 9 of the same can, L30.

4. *This step is optional (and expensive)*, but the change greatly improves receiver audio quality. Remove the narrowband filter (NFN 6000 AS) and replace it with the wideband version (NFN 6000 AW). See **table 1.**

To increase transmitter bandwidth, simply adjust the deviation pot (labeled IDC) for the appropriate level. This control is located near a small transformer (T1) on the transmitter board.

transmitter improvements

Getting the transmitter to operate on two meters is no major problem. If you want optimum performance from your unit, pad the transmitter with the components shown in **table 2.**

After you tune up the transmitter, check it for rf output. See **table 3** for the power output to be expected from your unit. If output is low, very carefully retune the transmitter and power amplifier. Also adjust R35 for 28 mA at JU-1.

table 3. Power output to be expected from H-23 and P-33 units with various power-supply conditions.

H-23 Series

1.0 watt at full battery voltage (135 Vdc)
0.8 watt at nominal battery voltage (120 Vdc)

P-33 Series

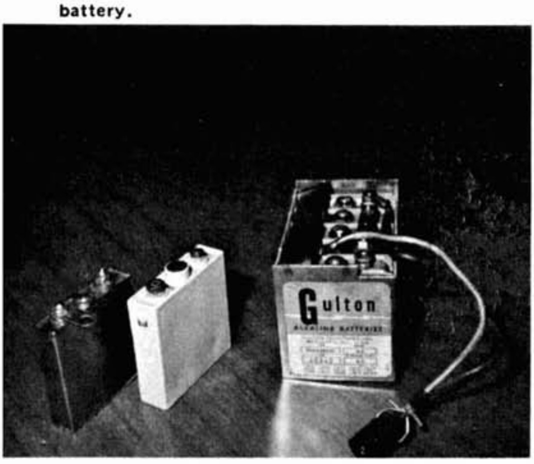
3 watts at 162 volts (dry cell nominal)
4 watts at 180 volts (dry cell maximum)
5 watts at 240 volts (nicad batteries)

multiplier and driver checks

It's very difficult to find a tube checker to test the multiplier and driver chain, so check the 2E24 in the power-amplifier cage, even though this tube seemingly never needs changing. After you've made further steps, such as voltage checks, you can feel confident that the third doubler and drivers are at fault. This is a common problem with P-33s. All these tubes are 6397s, and they'll set you back a fat $7.84 each.

Why did they go bad? There are a couple of possible reasons. The 6397 has a quick-heating filament. After awhile, a filament may not heat as quickly as it should. While transmitting, the driver tubes may not be getting any excitation, and they'll blow. Thus, all three usually go in "domino" fashion.

Nicad batteries in P-33BAM, H-23BAM series. From left, metal vented nicad cell; plastic-coated non-vented cell (nicad); vented nicad battery.



The second cause of tube failure is preventable. Some hams operate the P-33 directly from the car's ignition system. If a large enough voltage spike occurs, the 6397s will be zapped. Many fm'ers run their units like this with no trouble; then again, some aren't so lucky.

power-supply improvements

In equipment such as the P-33BAM, the "M" denotes a nicad-battery supply. Likewise, a "C" denotes a dry-battery pack in a P-33BAC.

There's not much to say about the dry-battery pack, because it's merely a box. The nicad supply, however, is a 6/12-volt dc-to-dc converter. Nothing seems to go wrong with the inverter, but every P-33 owner should become an expert on the care of the nicad batteries. After all, a new set of nicads would cost you only $128.50! Used nicads can be obtained for about $15, though, thanks to the surplus emporiums.

It's impossible to give a complete discussion on nicads here, but the following is advisable. If the nicad pack is vented, each cell will have a rubber gasket and a screw at the top. Sometimes the electrolyte leaks out of the vent and solidifies. Simply clean off the entire battery with clear water and a toothbrush. Make sure the vents are screwed shut when cleaning. If electrolyte is needed, place approximately two potassium hydroxide (KOH) pellets into the required amount of water for each cell. Do not saturate the electrolyte. Mix the solution well before putting it into the cell. (This procedure isn't necessary for nonvented cells.)

Incidentally, some of the batteries made by Gulton (for Motorola) are labeled "Alkaline Batteries." These are actually nicads. The batteries made by NIFE are plainly labeled nicads.

charging nicads

Measure the voltage of each cell. A fully charged cell should show 1.25 volts under load. If the cell shows zero volts, check it to determine if it's shorted. If so, the shorted cell should be replaced.

Each battery consists of five cells, and there are two batteries in the P-33. The H-23 has one battery, and the D-33 has none.

If you don't have a charger, the circuit shown in **fig. 3** will do the job nicely. An advantage of this circuit is that it will charge the batteries while they're installed in the P-33. You can also simultaneously charge batteries and operate the rig, providing you have a *regulated* 12-Vdc source.

With S1 in the *fast charge* position, the batteries receive a 375-mA charge. Ten hours are required to charge the batteries at a 400-mA rate; however, when S1 is in the *fast charge* position, the circuit charges at 375 mA as a safety precaution. Thus if the battery is fully discharged it should be charged for 10 hours; if half discharged, it should be charged for 5 hours, etc. A word of caution is an order.

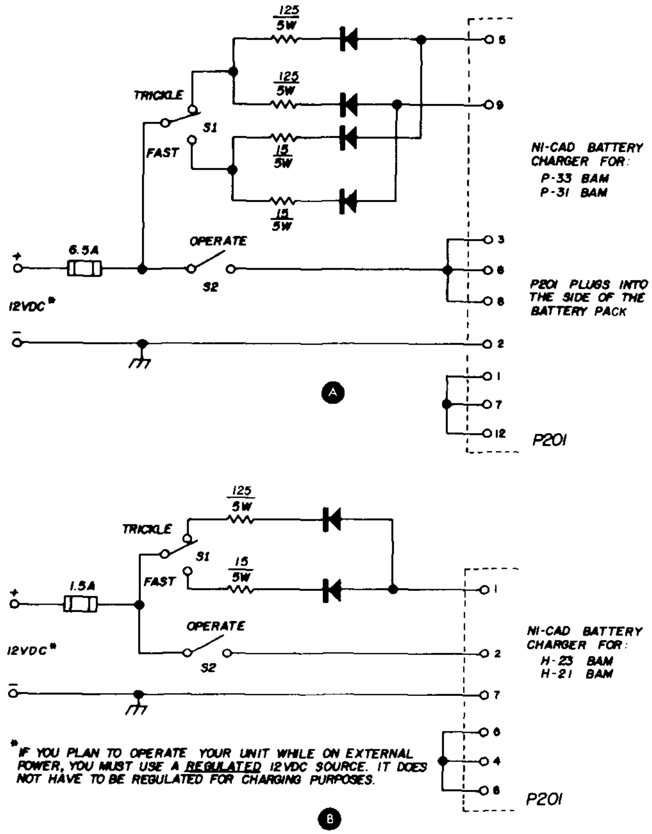


fig. 3. Nicad battery chargers. Circuit at A is for the P-33BAM, P-31BAM, etc. B shows circuit for H-23BAM and H-21BAM.

If S1 remains in the *fast charge* position too long, the nicads may explode.

When the batteries are fully charged, S1 may be placed to *trickle charge*. This will ensure fully charged batteries when you need them. The batteries can be trickle-charged continuously with no harmful effects. Discharged nicads should be recharged immediately after use. If you try to operate your P-33 on discharged nicads, the batteries might be permanently damaged.

acknowledgement

I'd like to express my thanks to WA2HXY and W1RYL for their assistance in the preparation of this article.

reference

1. L. Cobb, W6TEE, and J. O'Brien, W6GDO, "Amateur Fm and Repeaters," *QST*, October, 1969, pp. 11-13.

ham radio

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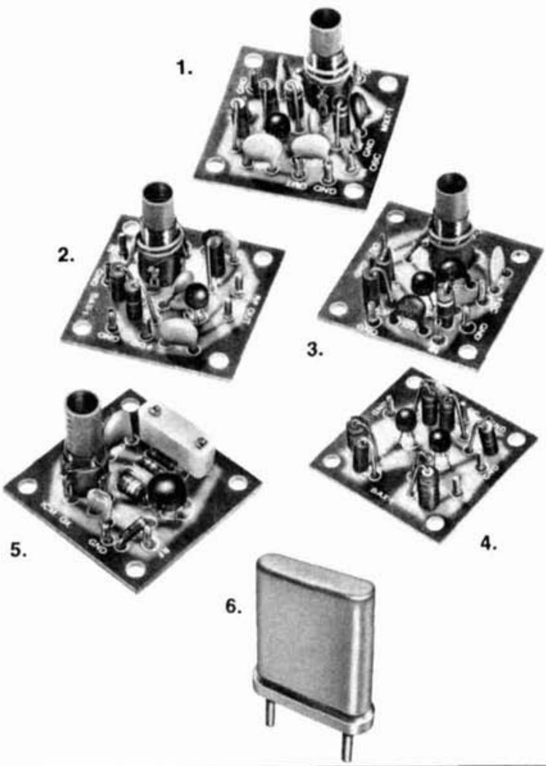

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A single tuned circuit intended for signal conversion in the 3 to 170 MHz range. Harmonics of the OX oscillator are used for injection in the 60 to 170 MHz range. Lo Kit 3 to 20 MHz, Hi Kit 20 to 170 MHz (Specify when ordering) **$3.50**

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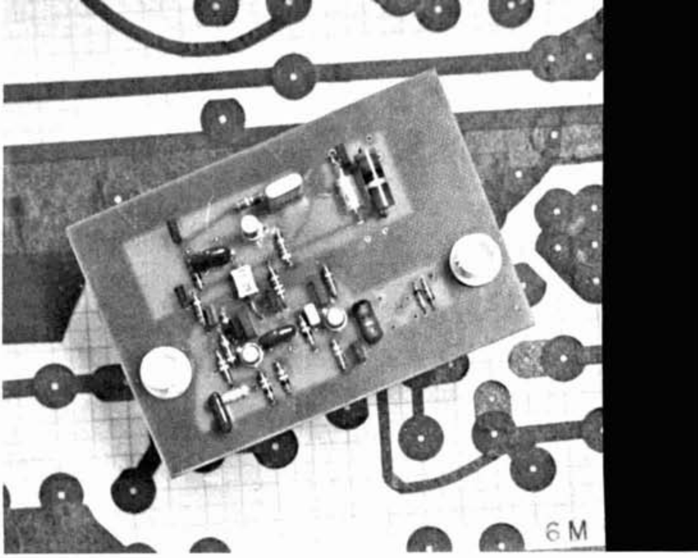
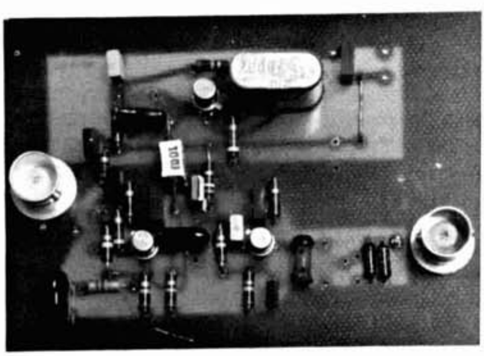


deluxe mosfet converters for six and two meters

Donald W. Nelson, WB2EGZ, 9 Green Ridge Road, Ashland, New Jersey 08034

High-performance vhf converters featuring gate-protected mosfet devices and simple construction

Since 1968 when the first mosfet amateur receiving converters were described in *ham radio,*[1] many hams have had the opportunity to prove their worth. I know of 20 such converters operating in the Philadelphia area alone. While the original design was easy to construct and produced troublefree operation, a redesign using a printed-circuit board and the latest transistors further simplifies the project. By combining the experience of many users it is possible to direct the builder in customizing his own system.

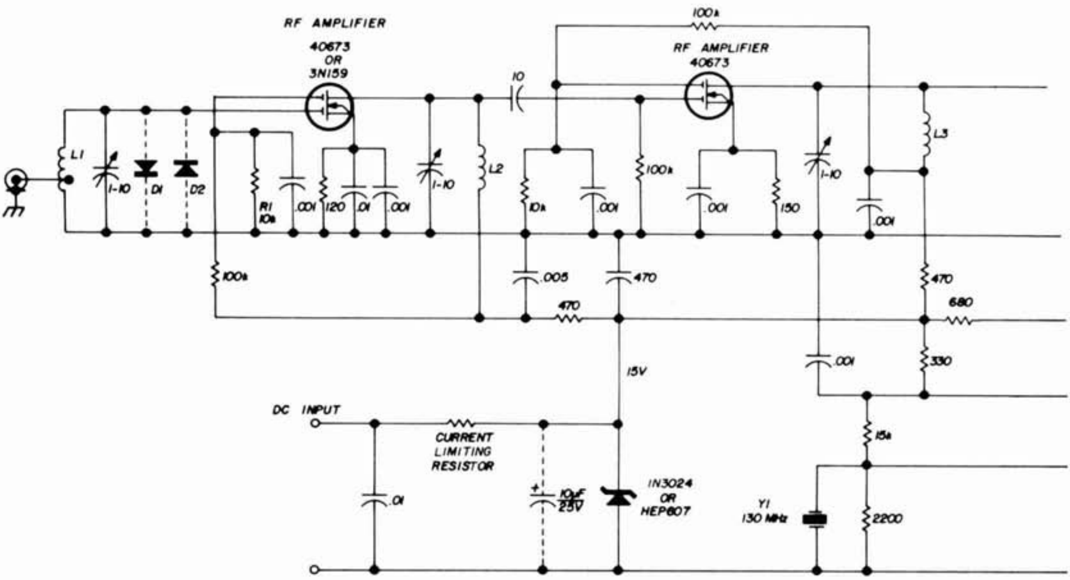


Top view of the six-meter converter. No zener regulation was used in this unit. I-f output is at 14 MHz.

choosing transistors

With the introduction of the gate-protected mosfet, most of the former problems with premature burnout are eliminated. At the time of this writing, there are three such transistors, the RCA 40673, 3N187 and 3N200. The 3N187 and 3N200 are basically the same as the 40673 but feature more tightly controlled operating characteristics. A list of protected and unprotected mosfets suitable for vhf use is given in **table 1**.

One disadvantage of the 40673, which may be overcome by using other mosfets, is the wide variation in characteristics that is possible. By selecting a 3N159 for the front end, the lowest noise figure is possible. Next in order of preference is the 3N140. This is also a good choice for the rf stage of the 6-meter unit and the second rf stage of the 2-meter converter. Performance comparable to the 3N140 is obtainable from Motorola's MFE3007. An RCA 40603 or Motorola MFE3006 would also be suitable as rf amplifier at 50 MHz. In the mixer – the least critical stage – lower gain transistors such as the 3N142 or MFE3008 are useful.

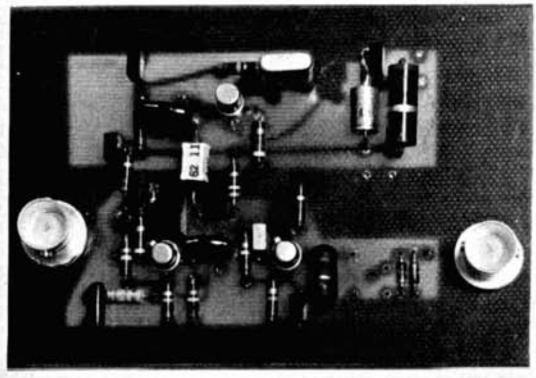


mosfet handling precautions

Since electrostatic charges can destroy the gate insulation on mos field-effect transistors, the devices must be handled with a certain amount of care. The following handling procedures are recommended:

1. Do not remove the external shorting

This six-meter mosfet converter has a 28-MHz i-f output. Note the zener regulator and large voltage-dropping resistor. The crystal is a small HC-18 type.



wire until all components are wired into the circuit.

2. Use a soldering iron with a grounded tip (3 wire).

The RCA 40673, 3N187 or 3N200 do not have an external shorting spring because they are internally protected against low energy charges. However, precautions 2 and 4 still apply. Mosfets

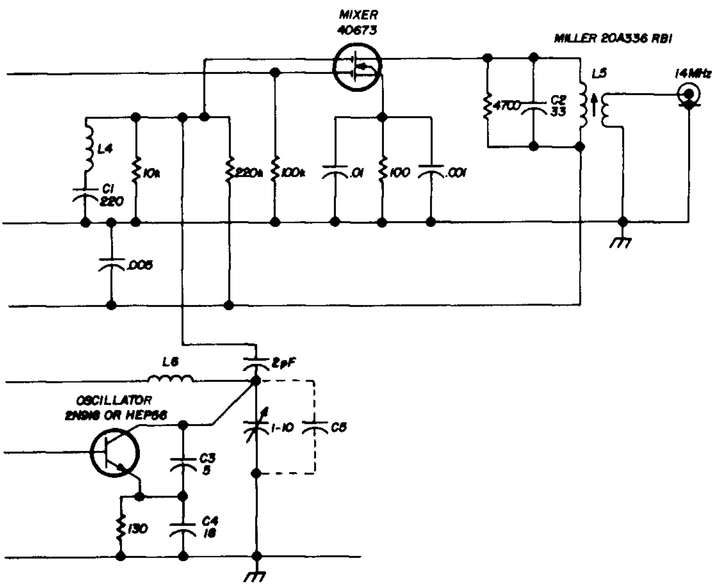


fig. 1. Circuit diagram for the deluxe mosfet two-meter converter. R1, for best noise figure, should be 33k; for maximum gain, 47k; for minimum cross modulation, 10k. Components given in parts list are for 28-MHz output.

L1 5 turns no. 16, ¼" diameter, tapped 1¼ turn from ground, air wound

L2 4 turns no. 22, ¼" diameter, air wound

L3 3 turns no. 22, ¼" diameter, air wound

L4 0.68 µH (J. W. Miller 4590)

L5 2.38 — 3.96 µH (J. W. Miller 20A336RBI) with 3-turns no. 26 output link

L6 5 turns no. 22, ¼" diameter, air wound

3. If any components must be added or removed, short the mosfet leads before proceeding.

4. If possible, isolate test equipment probes with a capacitor; some test equipment, usually old, has high voltages present which will destroy the transistors.

from Motorola such as the MFE 3007 are built differently and have higher breakdown voltages — one experienced user told me he experiences much less trouble with these. My own personal problems with mosfets have been few, but good clean living helps.

Both converters shown in this article are basically the same as the original

table 1. Operating characteristics of mosfets suitable for vhf converters.

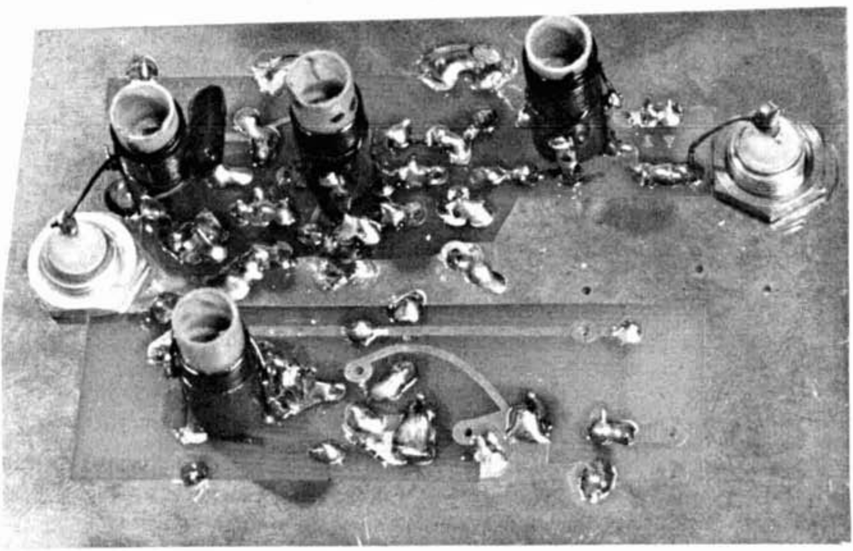
protected type	40673	3N187	3N200		
closest unprotected equivalent	3N140	3N140	3N159 or TA7153	3N159	TA7153*
maximum operating frequency	400 MHz	300 MHz	500 MHz	300 MHz	500 MHz
typical power gain at 200 MHz	18 dB	18 dB	19 dB	18 dB	na
typical noise figure at 200 MHz	3.0 dB	3.5 dB	3.0 dB	2.5 dB	na
maximum noise figure at 200 MHz	6.0 dB	4.5 dB	na	3.5 dB	na
typical power gain at 400 MHz	na	na	12.5 dB	na	14 dB
typical noise figure at 400 MHz	na	na	4.5 dB	na	4.5 dB
disadvantages	wide tolerances	—	—	unprotected gates	unprotected gates

na indicates information is not available
*not distributed through normal channels

design,[1],[2] although dual-gate mosfets are used throughout. One of the big advantages of the dual-gate configuration is that the converter may be optimized for gain, noise figure *or* cross-modulation resistance by changing one resistor, R1. This resistor, from gate 2 of the first rf stage to ground, should be 10k for lowest cross modulation, 33k for best noise figure, and 47k for higher gain. There is little advantage in making R1 larger than 47k because you can exceed the input rating of the transistors. The values of R1 shown here are experimental, and the operating characteristics will vary somewhat from one device to another.

Experiments with a hot-carrier-diode balanced mixer instead of the dual-gate mosfet were interesting. I found that unless the diodes were matched, there was no clear reduction in cross modulation over the mosfet stage.* In the presence of extremely strong signals, the two-rf-stage converter will have reduced gain – possibly to the point where weak signal reception is impractical. A single rf stage almost completely eliminates the effect.

The cost of unmatched hot-carrier diodes and their associated circuitry is four to five times more than the mosfet equivalent, and matched diode assemblies are even more expensive. From my experience, I feel that hot-carrier diodes should be reserved for higher frequency converters and other applications.

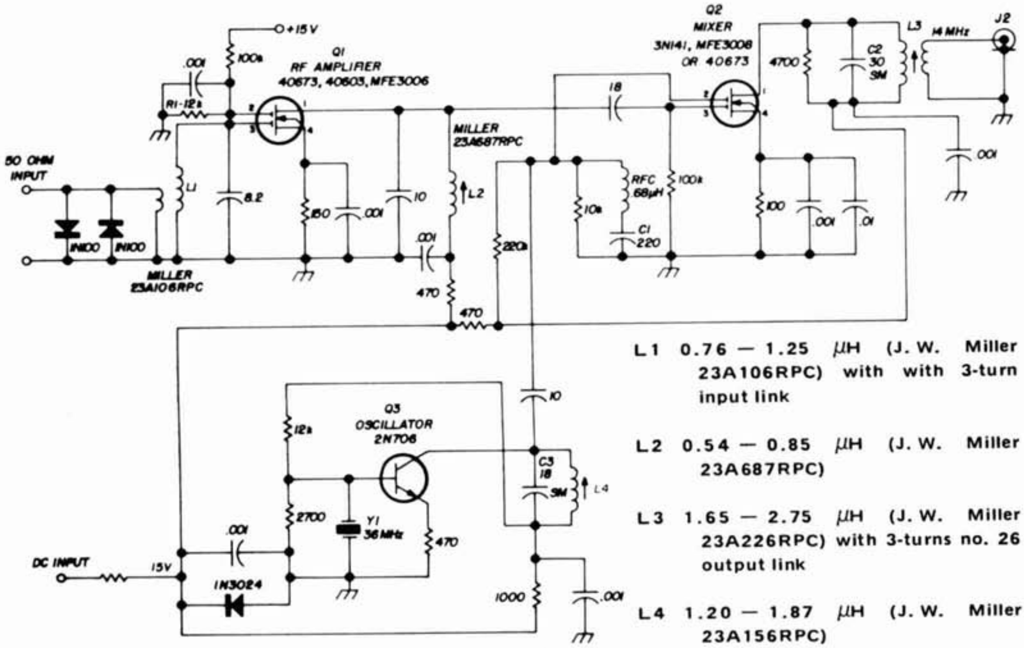


Bottom view of the six-meter converter with 14-MHz output. Coils have been mounted on this side to conserve space.

The oscillator of the two-meter converter has been upgraded by using a crystal at the injection frequency. This has the advantage of reducing the number of images. The higher cost of the crystal is compensated by reducing the number of components in the circuit.

The back-to-back diodes at the input are a very controversial subject. The amateur

*The experiment was conducted on two meters, with a 3N141 mosfet mixer, and a hot-carrier-diode mixer using Hewlett-Packard HP2900 diodes.



L1 0.76 — 1.25 μH (J. W. Miller 23A106RPC) with with 3-turn input link

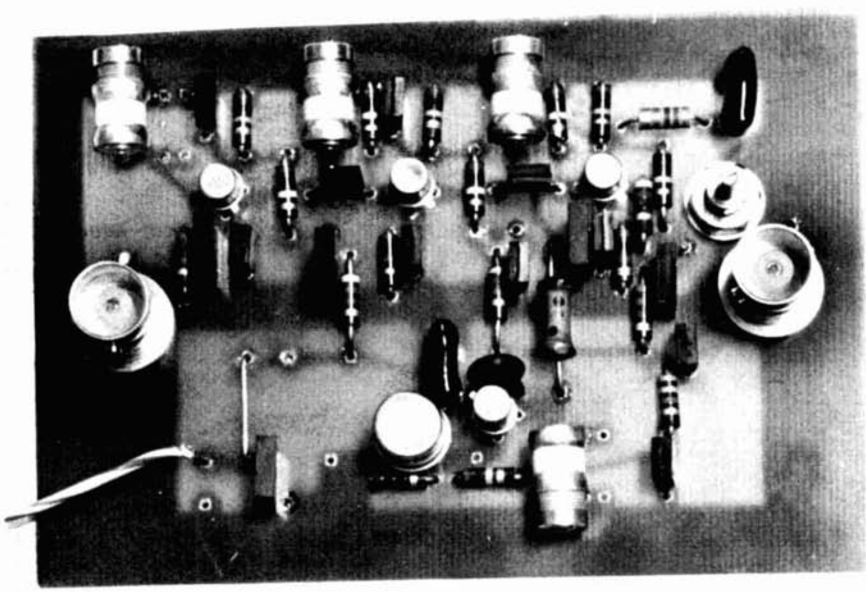
L2 0.54 — 0.85 μH (J. W. Miller 23A687RPC)

L3 1.65 — 2.75 μH (J. W. Miller 23A226RPC) with 3-turns no. 26 output link

L4 1.20 — 1.87 μH (J. W. Miller 23A156RPC)

fig. 2. Circuit diagram for the deluxe mosfet six-meter converter. Components with an asterisk are for operation from higher voltages (see text). Components in parts list are for 28-MHz output.

Top view of the two-meter converter. A special crystal is used in this model, but the more common HC-18 will fit equally well.



with a kilowatt (on any band) is going to need some protection, and the built-in diodes on the 40673 may not be enough. While 1N100s or 1N916s may protect

to use sequential relays on the same band, and to disconnect the converter when operating high power on other bands. The printed-circuit boards will accom date

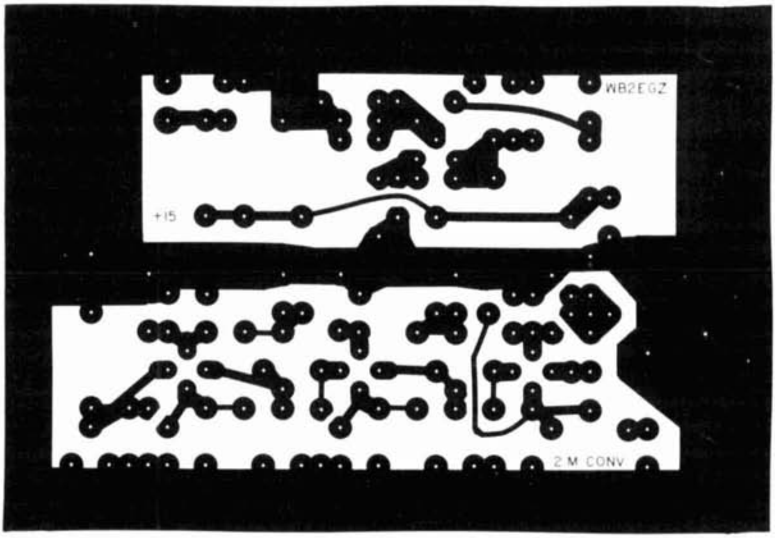


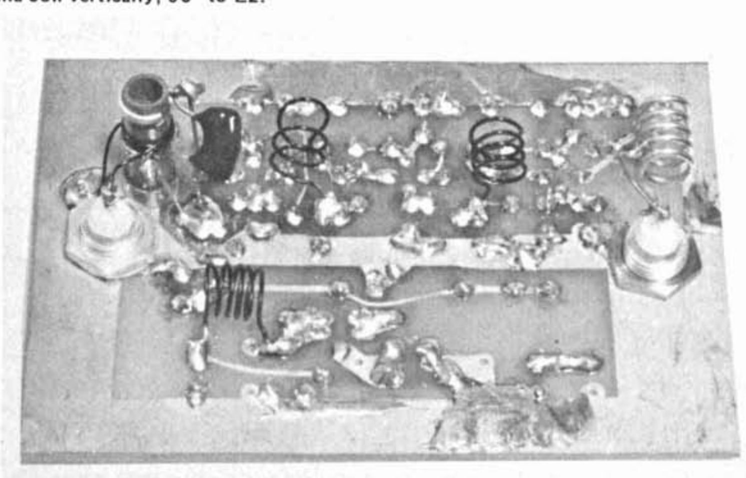
fig. 3. Full-size printed-circuit board for two-meter converter.

the transistors, they may cause TVI during transmission and severe cross modulation when receiving if a high-power transmitter is nearby. My answer is

the input diodes if you want to include them.

Layouts for the printed-circuit boards are shown in **figs. 3** and **4.** These boards

Bottom view of the two-meter converter. Stability of the first stage can be improved by mounting the antenna coil vertically, 90° to L2.



have been designed to include a 15-volt zener regulator and voltage-dropping resistor in case you don't have a convenient power supply. The value of the voltage-dropping resistor can be calculated on the basis of total current drain of 40 to 50 mA.

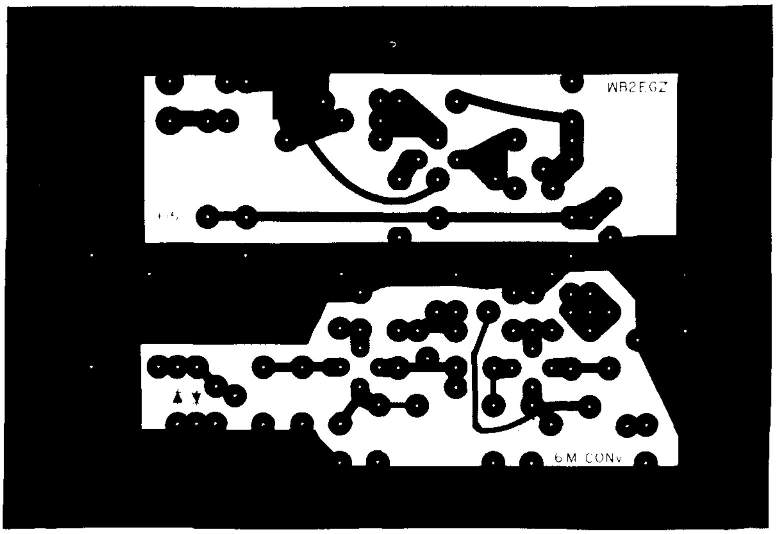


fig. 4 Full-size printed-circuit board for six-meter converter.

The printed-circuit design allows for a variety of components. For example, you can use an HC-6, HC-18 or HC-35 crystal holder. The trimmer capacitors may be replaced by feedthrough types if you want. And, except for L2 in the six-meter converter, the printed-circuit-type coils can be replaced by feedthrough equivalents. If you want to operate from a 12-volt source, replace the coupling resistors in the rf stages with 1.5 μH chokes in the two-meter unit, and a 6.8 μH choke in the six-meter converter.

tuneup

All tuned circuits except the output tank may be checked with a grid-dip oscillator, Dip the oscillator tank circuit a few MHz higher than the crystal frequency. Apply power and tune up on the band. In some converters the first two tank circuits must be stagger-tuned to avoid oscillation. Some broadbanding is normally desired anyway, so no shielding was included in early models. Later experiments showed that a simple shield between L1 and L2 helped stabilize the amplifier. The circuit may also be stabilized by broadbanding with a 2200-ohm resistor across L2.

The noise figure of this design has been measured from 2.3 to 3.0 dB, depending on tuning and individual difference between components. If you select transistors for noise figure, you can obtain somewhat better noise performance. I observed noise figures less than 2 dB at an East Coast VHF Conference in 1969.

I would like to thank Mike Ward, WB2YJK, Joe Bennet, WB2FDL, and Steve Wojcik for their contributions to this article.

references

1. Donald W. Nelson, WB2EGZ, "The WB2EGZ Converter," *ham radio,* June, 1968, p. 22.
2. Donald W. Nelson, WB2EGZ, "The Two-Meter Winner," *ham radio,* August, 1968, p. 22.

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troubleshooting the ST-6 RTTY demodulator

Complete troubleshooting instructions are given along with voltage measurements and theory of operation

Irvin M. Hoff, W6FFC, Los Altos Hills, California 94022

The article on the ST-6 in the January issue[1] was somewhat general in scope. There are several topics remaining which are of interest to the serious enthusiast, including voltage charts, trouble-shooting comments and more detailed analysis of circuit operation.

voltage measurements. These were all made with a Heathkit vtvm with the standard 10 megohm dc probe. The power supply had ±12.0 volts output. On each op amp, the voltages at pin 4 were about −11.9 volts, and at pin 7, about +11.9 volts. If you are reasonably close to these measurements and the ones that follow, you should expect normal operation in that part of the circuit. Other voltage measurements are shown in **table 1.**

Some latitude on these measurements is acceptable. The voltage with mark signal at test point 2 might vary from unit to unit, but should be 6 to 9 volts. All measurements on U1 should be pretty close to those given. On U2 most of the measurements will be pretty close; if the voltage at pin 6 is not between 7.5 to 9 volts, adjust resistor R'D' as explained later. On U3 the measurements will be very close again, with voltages at pins 2, 3 and 6 slightly less than at pin 6 of U2. U4 should be quite close to these. On U5 the voltages at pins 2 and 3 may vary a little, but the rest should be very close. On U6 and U7 the voltages should be pretty close to those shown in **table 1**.

On Q1, the voltages at the base should match very closely, although those on the collector can vary some. That is, with a mark signal, you might get from 0.5 to 2.0 volts; the voltage on space will depend on your loop supply and transformer, but probably will be between 140 and 200 volts. Q2 and Q2 voltages should match closely. The voltage on the base and emitter of Q3 may vary somewhat. The voltage on the collector of Q4 may be anything from almost zero to 0.2 volts. The voltages on Q5 and Q6 should be about the same as those in **table 1**. On Q7 the collector voltage with mark signal will be from almost zero to 0.2 volts, and the voltage on space might be anything from 8 to 10 volts.

troubleshooting

The first thing to check is power supply output; make sure you are getting close to ±12 volts. Then start with the U1 stage. Disconnect the input to the ST-6 and balance the pot for 0 Vdc output; then connect the input and insert a mark signal. Check the voltage at test point 2; it should be around 7 to 9 volts. Check the voltage at test point 3, it should also be around 7 to 9 volts. If more than 9 or less than 7, you might want to change resistor R'D' on U2 until you get close to but not more than 9 volts. Then pick an appropriate capacitor for C'C' from **table 2.**

By keeping the voltage close to 9 Vdc maximum dynamic range will be obtained for limiterless linear operation. If the voltage at test point 3 is allowed to exceed 9 volts, the input to U4 could (with RTTY being received) go higher than 4.5 volts and possibly damage U4, as the maximum differential input voltage for a 709C op amp is 5.0 volts.

If the output at test point 3 is around 8 or 9 volts, then the output at pin 6 of U4 should be approximately +10.8 volts. This should cause the printer to stay in mark. With a signal, the motor should have come on within 4 or 5 seconds or less; if not, the autostart system is not working properly or has not been adjusted correctly.

theory of operation

automatic printer control. Let's approach this from two different aspects. Let's say we have been printing an incoming signal; just this instant it quit and we are getting random noise from the receiver – the motor is still running and the receive lamp is still on.

With a random noise input, the voltage at test point 2 will vary from one moment to the next, but in any event it should be less than the 7.5 volts or so you had when the signal was present. Thus, the fixed bias on the non-inverting input of U5 will be greater than that coming to pin 2 of U5. (The two 68k resistors, R66 and R67 reduce the voltage at test point 2 to one-half so that the 5.0 volt input limit of U5 will not be exceeded.) Thus U5 is now controlled by the voltage at pin 3, and the output is approximately +11 volts. This is passed by CR27 and charges the 350 μF capacitor C21 through R61.

Since C21 is in parallel with a resistor network, the capacitor takes 0.8 to 1.0 second to charge. As it charges, the voltage at terminal 3 of U6 rises to about 4.7 volts. As it goes above the 2.2 volt fixed bias level on pin 2, it takes charge of U6, which then flips to positive output of about +11 volts. This is blocked by CR25 but passed by CR24, and applied to the standby line, which causes Q1 to conduct and puts the printer into mark-hold.

At the same time, the 20-μF capacitor

table 1. Dc voltage measurements in the ST-6 RTTY demodulator.

pin	Op Amp U1 mark signal	Op Amp U2 mark signal	Op Amp U3 mark	Op Amp U3 space
1.	7.8	8.2	8.2	
2.	0	0	8.5	-8.5
3.	0	0	8.5	-8.5
4.	-11.8	-11.9	-11.9	
5.	-11.4	-11.4	-11.5	
6.	7.7 Vac	8.4	8.5	-8.5
7.	11.8	11.9	11.9	
8.	9.4	8.7	8.5	

pin	Op Amp U4 mark signal	Op Amp U5 signal	Op Amp U5 no signal	Op Amp U6 signal	Op Amp U6 no signal
1.		7.4	8.2	7.5	8.1
2.	0	3.9	0	2.2	2.2
3.	2.0	3.4	3.4	0	4.7
4.		-11.8	-11.8	-11.9	-11.9
5.		-11.0	-11.9	-10.8	-11.9
6.	11.0	-10.8	11.4	-10.8	10.8
7.		11.8	11.8	11.9	11.9
8.		11.5	7.8	11.4	7.7

pin	Op Amp U7 mark	Op Amp U7 space
1.	7.5	8.1
2.	2.3	2.3
3.	0	4.2
4.	-11.9	-11.9
5.	-11.9	-11.9
6.	-10.8	10.8
7.	11.9	11.9
8.	11.5	11.5

	Q1 mark	Q1 space	Q2 S3 on	Q2 S3 off	Q3 signal	Q3 no signal
B	0.6	-0.7	11.3	12.0	-10.3	0
E	0	0	12.0	12.0	-9.5	0
C	1.0	170	11.9	0	-12.0	-12.0

	Q4 signal	Q4 no signal	Q5 signal	Q5 no signal	Q6 signal	Q6 no signal	Q7 mark	Q7 space
B	-0.7	0	-11.3	-12.0	-11.9	-11.3	0.7	-0.7
E	0	0	-12.0	-12.0	-12.0	-12.0	0	0
C	-0.03	-12.0	-11.8	+10.2	+12.0	-11.8	0.05	9.3

Test point 2: Mark signal, 170 shift discriminator 7.8 Vdc; input to ST-6 disconnected, 0 volts.

C20 no longer has any voltage to keep it charged, so its 9- to 10-volt charge starts to bleed off slowly. When it has dropped to less than −0.6 or −0.7 volts, Q3, Q4 and Q5 stop conducting, causing the relay to open and the motor to turn off.

At this time Q6 conducts, pulling about the same current through the 500-ohm resistor R47 that the relay had been pulling through Q5. Thus the drain on the power supply remains rather constant, and better regulation is possible. In fact, at the time this particular part of the circuit was developed I had not intended

table 2. Correct values of C'C' for different values of R'D' (see fig. 5, reference 1). Resistor R'D' is chosen for 9 volts at test point 3 with a mark input (see text for discussion).

R'D'	C'C'
300k	.018 μF
270k	.02 μF
240k	.022 μF
220k	.025 μF
200k	.027 μF
180k	.03 μF
160k	.033 μF

to use any type of regulation in the power supply at all.

For the next configuration we have the motor off, and there is no signal. Now we suddenly get a signal into the ST-6. The voltage at test point 2 goes to approximately 7.5 volts. This becomes around 3.8 volts at pin 2 of U5 and as this is somewhat more than the fixed bias (3.2 volts) at pin 3, the output switches from +11 volts to −11 volts. (Pin 2 is called the "inverting input," and a positive signal becomes negative at the output.) This voltage is blocked by CR27, so the 350-μF capacitor C21 starts to bleed off through R59 and R60.

As the voltage at pin 3 falls lower than about 2.2 volts, the fixed bias on pin 2 takes over, and the output of U6 flips from positive to negative output. This is blocked by CR24, so now the standby system is removed and the printer is free to follow the incoming signal. At the same time the negative output of U6 is passed by CR25, so the 20-μF capacitor C20 is quickly charged through the current-limiting resistor R55.

As this happens, Q3, Q4 and Q5 all conduct, closing the relay and turning the motor on. This causes Q6 to stop conducting, so again the current in this part of the circuit is similar to what it had been when the relay was not being used.

At this point it is worthwhile to mention how the circuit could be changed to a "fail-safe" type. The relay could be placed in the collector of Q6, and resistor R47 would then be in the collector circuit of Q5. The relay would be activated any time the motor was supposed to be off (the back contacts on the relay would be used for the motor), and if the relay or any part of the ST-6 failed, the motor would come on automatically. However, with solid-state circuits there is not too much reason to worry about a fail-safe system.

fast-slow switch. This consists of a 150-μF capacitor C22 in series with the 350-μF C21. The total capacitance in "fast" then becomes about 85 μF, and the circuit responds in about one-fourth the normal time, making attended *fast-break* operation possible, yet retaining the features of automatic printer control. Switch section S4B operates at the same time to keep the motor running. This type of circuit is not suitable for unattended operation due to the short time constants.

anti-space. This circuit is quite interesting, and some knowledge of how it works is beneficial. Basically it puts the printer back to markhold if the input signal goes to space for longer than a normal RTTY character. This also prevents the autostart from activating if a signal appears in the space channel. Therefore, if a station is playing around with his shift and going between mark and space, your machine will not run open.

With a mark signal a positive voltage will appear at the output of U4, causing Q7 to conduct. Its collector then goes to less than 0.2 volts, effectively short-circuiting the 10-μF capacitor C19. The 330-ohm resistor R40 is there to limit current through the transistor as it suddenly shorts this capacitor. The voltage at pin 3 of U7 now becomes approximately 0.1 volt or less, and the 2.5 volts fixed bias on pin 2 takes over, putting negative voltage out of U7. This is blocked by CR21 and CR22, so nothing at all happens.

With a space signal the output of U4 negative, so Q7 stops conducting and is biased off, the voltage held to −0.7 by the protective diode CR20 in its base. The 10-

μF capacitor is now charged to about 9 volts. This becomes about 4.0 at pin 3 of U7 as the network is provided to keep this less than the 5.0 volts maximum allowable input. It will take about a quarter-second for the voltage at pin 3 to build up more than the 2.5 volts fixed bias on pin 3. When it does, U7 flips to positive output, and the voltage is passed by both CR21 and CR22. CR21 goes to the standby line, and puts the printer into markhold. At the same time the voltage through CR22 goes to the automatic printer control line and starts to charge up the 350-μF capacitor C21. This will take 0.8 to 1 second, putting the system into "autostart off."

As this happens much faster than the incoming signal could discharge that capacitor, the motor would never turn on should an incoming space signal be received, and if a signal suddenly goes to space after printing authentic RTTY, the autostart would soon be disabled, and 20 to 30 seconds later the motor would turn off. The anti-space works equally well whether the limiter or autostart are on or off, or whether the incoming signal is being "straddle-tuned" due to incorrect shift.

No provisions were provided to disable the anti-space. However, if you need this feature for any reason, just short the collector of Q7 to ground. A switch could be permanently added for this purpose, if needed.

fsk output. With nothing connected to the J3 keyer jack, the voltage there should swing from approximately −35 volts on mark to +35 volts on space. Without the 12k resistor R31, this voltage would be around 70 volts or so, which is enough to destroy most germanium diodes used in typical fsk circuits. When the fsk system is plugged into J3, the current on conduction is held to 4 or 5 mA by the 8.2k resistor R30, offering suitable saturation for good keying of the transmitter.

the threshold corrector. I have not said much about this circuit, and indeed it is complex enough to merit a complete article of its own. Perhaps a few words will help you understand its operation. If a steady mark signal is present, the voltage at test point 3 will be about 8.5 volts. Let's call this 8.0 volts for the time being. This voltage would charge C6 and also be passed by CR10, eventually going through R18, R19 and CR13 to ground. Thus, the voltage at the input of the normal-reverse switch would be roughly 4.0 volts. (There is another network in the normal-reverse switch which further drops this 4.0 volts to 2.0 volts at pin 3 of U4; this will be explained in a moment.)

With steady mark of 8.0 volts, the output of the atc section is 4.0 volts and the input to U4 is 2.0 volts. If you now flipped suddenly to space, you should get the same 8.0 volts at test point 3; however it would now be −8.0 volts. This would be passed by CR11, and on to ground through R19, R18 and CR12, again putting −4.0 volts at the output of the atc system. This negative −8.0 volts would also charge C5.

The interesting thing that happens on a quick reversal such as this, however, is that the previously charged capacitor C6 now discharges, adding another −8.0 volts to the system, which is reduced to 4.0 volts by the action of R18 and R19; thus you get the −4.0 volts from test point 3, plus this capacitor discharge voltage of an additional −4.0, making a total voltage at the output of the atcc system of −8.0 volts.

With steady input of mark or space, you would have half that voltage appearing at the output of the atc circuit, but with steady reversals (RTTY characters), the voltage on the output would be approximately equal to the original input. Therefore, the new voltage at the input of U4 would be about 4.0 volts. The reason for the 220k resistor network now becomes more apparent, if you remember that the input of U4 cannot safely exceed 5.0 volts.

If copying mark-only signals but with RTTY reversals, it can be shown that the voltage at test point 3 would be roughly

+8.0 volts for mark and close to zero volts for space if you assume for a moment that the system doesn't particularly respond to noise alone. In this case you would have an on-off voltage instead of the plus-minus swing previously mentioned with normal two-channel RTTY.

I could show that the voltage at the output of the atc would go from +4.0 to about −4.0 volts and the voltage at the input of U4, instead of being ±4.0 volts with normal RTTY, would be ±2.0 volts with mark-only RTTY. Since the slicer is operated in an open-loop configuration, anything more than a few microvolts plus-and-minus will cause it to operate suitably. The important thing is to keep the information properly centered plus-and-minus, not *how much* it swings one way or the other.

The atc is a most fascinating circuit, and goes a great way in counteracting for signals that drift, for shifts that are incorrect, and even to some extent, for signals that have distortion on them when received.

An important thing most RTTY enthusiasts overlook is the diversity effect offered by such a system, as it actually samples both the mark and the space signal and uses either or both to provide proper information to the slicer. A system such as that used in the ST-6 actually offers diversity reception with only one antenna, one receiver and one converter. At one time commercial stations had to go to dual-diversity reception to allow for selective fading. This required two antennas, two receivers and two converters that fed into a diversity combiner. All this duplication was beyond the ability of most amateurs (and many commercial and military installations as well) so other means of improving the signal had to be found. The atc represents one of the best of such solutions.

Another system which is much more sophisticated but built around the same concept is called dtc (decision threshold computer) and was patented by Page Engineering for use on the Dew-line defense system. As long as the limiter is used, for all practical purposes atc works as well as dtc. With the limiter off, the dtc has some advantages, particularly in slow hand-speed transmission, but it does not work well at all if mark-only handsent transmissions are being used. (Neither system works well on slow-speed space only.)

Thus, from a practical standpoint atc was selected for the ST-6 rather than dtc. With the simple linear discriminators used in the ST-6 (and most TT/L-2 units), limiterless copy has little to offer. You also lose stability of tuning indicator information, whether using the meter or an external scope, and you lose the ability to include automatic printer control. Finally, with low voltage solid-state circuits, the dtc is not at all practical in the form most amateurs have seen it.

I did develop a dtc system for 12-volt systems, but it took a total of 8 op amps, and to be compatible, you would have to add active detector circuits that require two more op amps. All this seemed too stiff a penalty to pay for the occasional limiterless operation an individual might use. If going to that extra work, then it seemed silly to retain simple linear discriminators. As a consequence, the ST-6 is presented in a form that represents excellent performance, with practical considerations rather than going for the very complex unit that could have been designed. As an example, if you were to build a really top-of-the-line unit with sharp mark and space filters (three toroids each) then you would find it difficult to use the unit at all if somebody's shift were off a little bit. As you are no doubt aware, few amateurs actually are within 50 Hz of 850 to start with, so practical considerations almost immediately rule out using first-rate filters anyway. Other examples could be used to show why, with present circumstances, you might not want such a unit even if it was offered.

no automatic printer control. While I think you ought to build the ST-6 pretty much as presented, some people still insist they do not need the autostart features. They would probably not want the anti-space either in this case, in order to save additional construction costs. The ST-6 was laid out so that all you need for similar performance is a loop supply, a ±12 volt supply, the U1, U2, U3, U4 and Q1 circuitry, and a switch from the collector of Q1 to ground for standby. That would do it. If that is still more than you need for RTTY work, forget the ST-6 and build the ST-5 presented in the September, 1970 issue of *ham radio.*[2]

summary

For those of you interested in learning more about solid-state circuits, this brief review should help. In any event you will better understand how the ST-6 works and what the various systems are supposed to do. It has taken me about six years of development to reach this phase, and there were many interesting thoughts picked up along the way. I feel the ST-6 will not be obsoleted or antiquated in any way for some years to come, although some designers may wish to use more exotic filters, or newer op amps, or add digital logic for autoprint.

Incidentally, Sel-cal devices[3] attach to the ST-6 with only a 10k resistor and a silicon diode. Since only a few dozen of the Selcal units have been built, write to me if you need that information. Large, easy-to-read schematics are still available from me for $1, postpaid anywhere in the USA or Canada; add $1 for air mail to other areas. Over 400 amateurs have requested schematics as of this writing, so it seems evident that the ST-6 promises to be one of the most popular RTTY demodulators of all time.

references

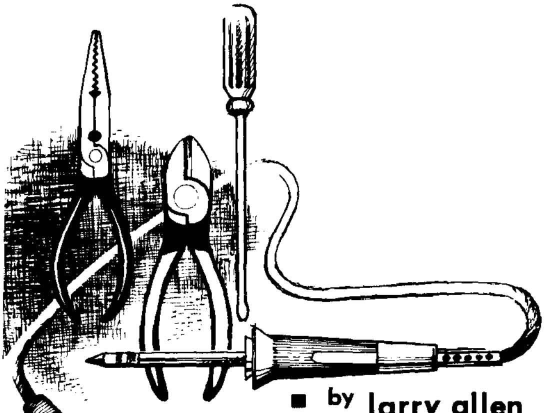
1. Irvin M. Hoff, W6FFC, "The Mainline ST-6 RTTY Demodulator," *ham radio,* January, 1971, page 6.

2. Irvin M. Hoff, W6FFC, "The Mainline ST-5 RTTY Demodulator," *ham radio,* September, 1970, page 14.

3. W. Mallock WA8PCK, and T. Lamb, K8ERV, "The Selcal – An RTTY Character Recognizer," *73,* May, 1968, p. 58.

ham radio

More Details? CHECK–OFF Page 94



the repair bench

by larry allen

thinking your way through repairs

The editor sends me a lot of letters from fans of the *repair bench.* Many of them ask for help with this or that problem. Naturally, I can't answer them all. Yet, there should be some way to help you, and perhaps what I'm writing about this month will do it.

Very few hams are professional repair technicians. If they were, they'd probably get enough of electronics all day long and wouldn't fool with it as a hobby. But when something goes wrong with your gear, even knowing exactly how it's built and how it works doesn't always lead you to the defect very quickly. At those times you probably wish you were a technician trained in hunting down electronic faults.

I can't train you in a few magazine pages to be a technician. But I can show you a technique used by professionals in home-entertainment electronics.

There's one method that should be easy to learn. It's called *1-2-3-4 Servicing.* It was originated by Forest H. Belt in some books published by Howard W. Sams & Co. Although the books are not about ham gear, I could see immediately how easily the method applies to any kind of electronics. So here's how *1-2-3-4 Servicing* can be applied to equipment on your ham repair bench.

thinking in sections

The important thing about 1-2-3-4 Servicing is the way you think. You have to think of electronic equipment in an orderly fashion. For that purpose, all electronic devices are split up into four logical divisions. They are sections, stages, circuits, and parts.

First, you think *sections.* Take a ham receiver, for example. It has an rf section, i-f section, audio section, and power supply section. These are sketched for you in **fig. 1.** You might be tempted to break it down further, but these are the breakdowns you use for 1-2-3-4 Servicing.

A transmitter divides up into the speech or audio section, rf generating section, modulated rf section, rf power section, and power supply section. If the transmitter is ssb, there is also a frequency-change section. Transmitter sections are illustrated in **fig. 1,** too, and the comparison with the sections of a receiver may help you see what sections really are.

The distinction that identifies a section is simple: *A section handles only one kind of signal.*

In a receiver, for example, the rf section handles incoming stations. The i-f section amplifies the station signal only after it has been heterodyned down to the intermediate frequency of the receiver. The audio section handles voice signals alone, after they have been demodulated from the i-f signal.

In a transmitter, as long as audio (voice or speech) is by itself the audio section handles it. The rf signal, as long as it's alone, is in the rf-generating section. Once modulated, the signal is handled by a different section. If the transmitter is ssb, a frequency-changing section takes the modulated signal and changes its frequency to the transmitting frequency. Once the modulated signal is at the output frequency, an rf power section boosts it.

That's how you can identify sections in any kind of electronic gear. When the signal changes character, consider it as going into a different section.

stage by stage

The second division you think of for 1-2-3-4 Servicing is *stages.* Sections are divided into stages.

For example, the rf section of a ham receiver has at least three stages. They're shown in **fig. 2A.** There may be more than one rf amplifier stage. A stage usually comprises one tube or one transistor and the parts that go with it. A stage either generates or amplifies or alters a signal.

Inside this rf section, the oscillator stage produces a plain rf signal. The rf amp gives a boost to the signal picked up by the antenna (which can also be considered a stage). Both signals go to the mixer. That stage changes the character of the rf signals, mixing them together and coming up with a signal at some intermediate frequency (their difference).

The i-f signal still has the station modulation that was on the rf signal. But the character of the signal has changed. It takes a different kind of stage to handle it. So the mixer stage has introduced the signal from the rf section into the i-f section.

The mixer stage, though officially part of the rf section, is an *interface stage.* It interfaces the rf section to the i-f section. The stage that creates the character change in the signal is an interface stage.

The detector or demodulator following the i-f amplifier stages is an interface stage. It extracts the voice signal that is part of the i-f signal. Once demodulation takes place, there is no more i-f signal — only the voice or audio signal. So the detector stage interfaces the i-f section to the audio section. Amplifier stages in the audio section handle only audio signals.

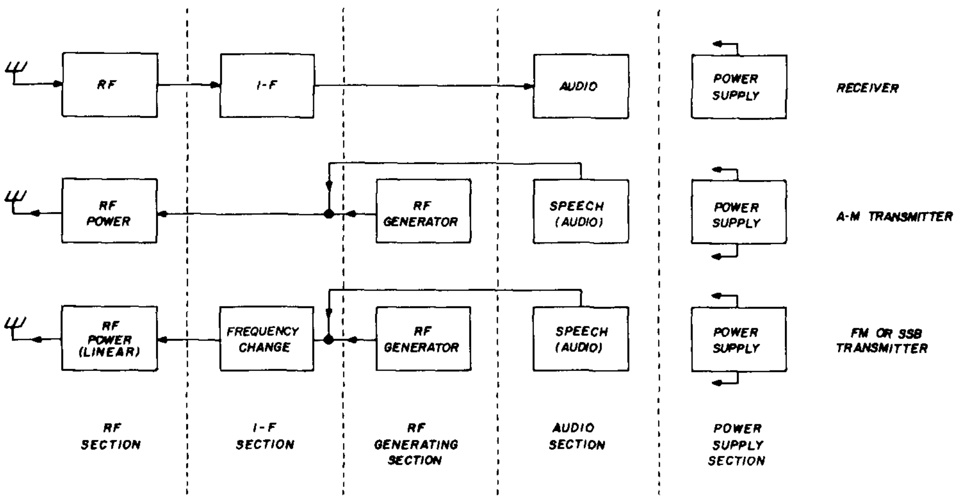


fig. 1. Sectionalizing ham equipment helps track down faults. Sections of different kinds of equipment are amazingly alike — if you learn the sections of one it's easy to divide up other electronic gear in this way.

If you want to carry the idea further, the speaker is a stage of the audio section. Actually, it's an interface stage between the audio section and the air. It converts the electronic audio signal into audible sound waves. That's what any interface stage does: change the nature of the signal between two sections.

An interface stage is always considered part of the section preceding. Sometimes it takes signals from more than one stage, as the mixer does in the rf section of a receiver.

Or, a stage may interface more than two sections. **Fig. 2B** has an example of this. This is the stage-by-stage division of an ssb transmitter. Stages are grouped

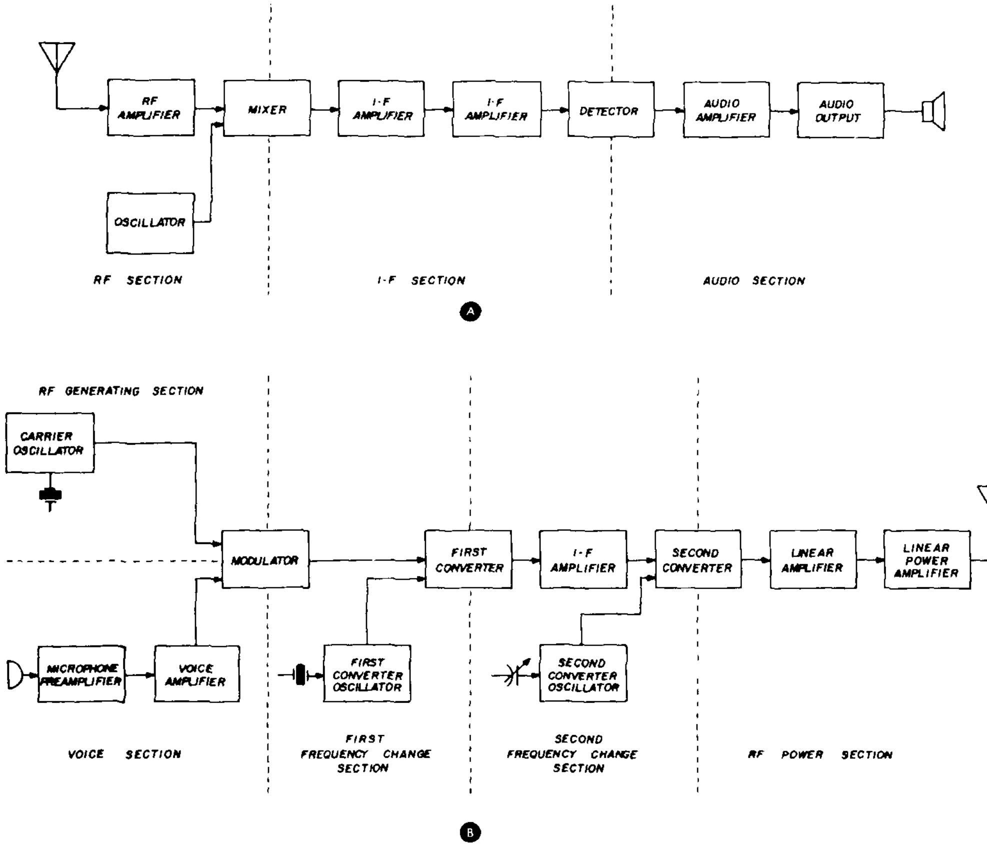


fig. 2. Sections divided into stages. For troubleshooting your work is cut down tremendously if you only have to test the stages in one section.

into sections so you can see the relationships. The voice section and rf-generating section are interfaced with the first frequency-change section by the modulator stage.

The voice section has two stages. The rf generator section (which can be called the *carrier* section in an ssb transmitter) also has two: the carrier oscillator and the modulator. It's customary to consider the modulator as an rf stage rather than a voice or audio stage, even though it involves both kinds of signals. The modulator takes the two signals and transforms them into a modulated rf signal. That calls for a different section, so the modulator is an interface stage.

The first converter stage interfaces the first frequency-change section to the second. This ssb transmitter uses double conversion to arrive at the output frequency. The amplifier stage in the second frequency-change section is called an i-f amp. (In a few transceivers, it's the same i-f amp used during receiving.)

The modulated i-f signal goes to the second converter, the interface stage between the second frequency-change section and the rf power section. A second conversion oscillator stage furnishes the unmodulated signal for conversion. The output of the second converter is a modulated rf signal at the output frequency.

All that remains is to amplify the output signal to full output power of the transmitter and feed it to the antenna. The rf power amps and antenna are stages of the rf power section.

what a circuit really is

That should give you a good idea how

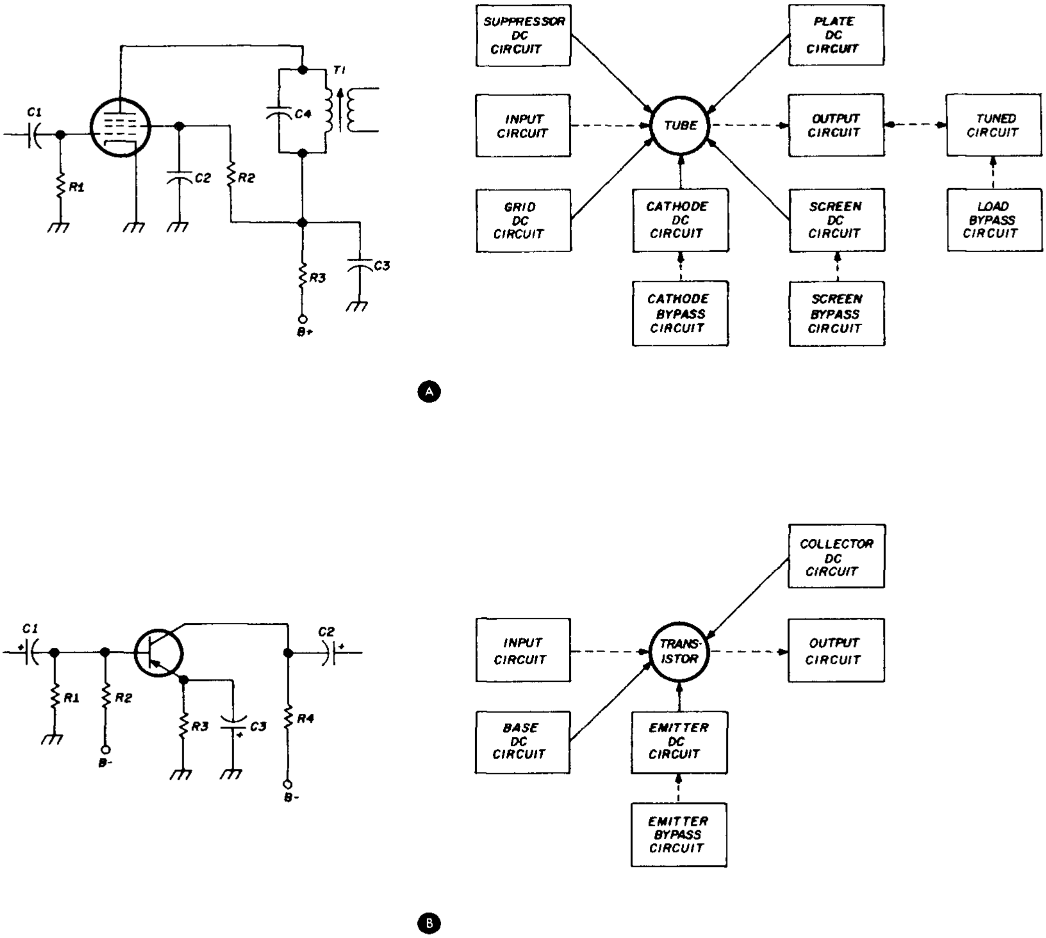


fig. 3. Identifying circuits in tube and transistor stages. Among circuit not shown here are feedback circuits (such as in an oscillator) and power-supply decoupling circuits (which aren't always drawn on schematics).

to think in sections and stages. Be sure you understand these divisions, because they're important in applying 1-2-3-4 Servicing.

The third logical division of electronic equipment is the *circuit.* Many hams – and a lot of technicians, too – think of circuits as being the things just described as stages. That's confusing. Actually, stages are made up of circuits.

Remember, a stage is a tube or transistor and the parts that go with it. Those parts are connected into *circuits.* There's an input circuit and an output circuit; a grid circuit, plate circuit, cathode circuit, and perhaps a screen circuit; a base circuit, emitter circuit, and collector circuit; there may be a feedback circuit, a tuned circuit, and so on. Any given tube or transistor stage has several circuits.

What you name the circuits depends on how you're considering the stage. For example, the tube and transistor stages in **fig. 3** have both dc and signal circuits identified for you. Solid arrows are for dc, and dashed arrows for signals.

The input circuit in both stages is C1 and R1. C1 is the input coupling capacitor, R1 the input load.

The output circuit for the tube is T1, C4, and C3. T1 and C4 are a tuned circuit that is the main load, and C3 is the load decoupling or bypass part of the circuit.

At the same time, the plate dc circuit

includes the primary winding of T1. The whole plate dc circuit is through R3 and T1. Thus some components must be involved in your thinking for more than one circuit.

Indeed, some components are in more than one circuit. Resistor R3, for instance, is in the screen dc circuit as well as in the plate dc circuit. In troubleshooting, you'd naturally expect a bad R3 to affect both dc circuits. And it would.

By the same token, R1 in the transistor stage is part of the input circuit for signals. Yet, at the same time it's part of the base dc circuit; it's part of divider R1-R2 which sets base bias. Resistor R4 is the output load, and is also in the dc collector circuit.

Two bypass or decoupling circuits are invisible in **fig. 3B.** Anytime a B-plus or B-minus connection is shown in a schematic, you must remember that it includes a filter capacitor, which is usually in the power supply. But it is part of the signal circuit of any stage fed from that leg or branch of the power supply.

When troubleshooting, don't ignore this bypass circuit. In **fig. 3B** a filter capacitor is part of the output load circuit, forming the ground return for signal at the bottom of R4. The bypass capacitor at the B-minus end of R2 makes R2 a part of the input load, in parallel with R1.

what makes up a circuit?

Of course the answer to that question is *parts.* You've already seen that, in my description of what a circuit is. And parts are the fourth division of electronic equipment.

One secret of 1-2-3-4 Servicing is this manner of thinking. You consider all electronic equipment in terms of these four divisions. You think of a receiver or transmitter as divided into sections. The sections, you think of as divided into stages. Stages are in turn divided into circuits, and those are divided into individual parts.

The four steps of thinking are, therefore: sections, stages, circuits, and parts.

Once you've learned to think of your ham gear as made up of sections, stages, circuits, and parts, you can use those divisions in an exceptionally logical way when trouble occurs. Here's how the 1-2-3-4 Servicing method works.

The first step is *diagnosis.* You diagnose which section of the faulty instrument has the trouble in it. There are three main helps to diagnosis.

One is to know the equipment. Be familiar with it. Study the schematic and read the instruction manual. Read books about it. Gain knowledge of it through experience. Once you're familiar with a receiver or transmitter, you know what sections it has. That aids diagnosis. For example, if a transmitter puts out rf, but not modulated, you know the trouble must be in the voice section.

Another approach to diagnosis is inspection. *Look* inside the unit. *Listen* to a receiver. Or listen to the relays of a transmitter. Or listen for some unnatural sound like a resistor or transformer frying or something arcing. *Sniff,* and sometimes *touch* – perhaps to sense overheating. In other words, use your senses to inspect the unit. They may help you diagnose which section has trouble.

And of course you diagnose by observing symptoms. Is the unit completely dead? Does some portion of it work? Some one function not work right? Do the operating controls work as they're supposed to? How about service adjustments? Such analysis of symptoms can point strongly to which section of a transmitter or receiver is bad.

the second step

Once you diagnose the faulty section, your next step is to *locate* the defective stage. Since you already know the faulty section, you have only a few stages to check. Instead of checking a whole setfull of stages, you check only two or three – those in the section you diagnosed.

You might locate the faulty stage by observing symptoms, or by noticing how certain controls react. But more likely you'll use instruments.

You already know there are two ways to look at stages. They are dc-operated, and they handle signals. You can test them for either kind of operation. You can inject a signal at the input of a stage and see how it travels through the remainder of the set. Or, you can use a tracer to see how far a signal gets, to see what stage stops it or distorts it or somehow fouls it up.

Or, you can measure dc voltages on stages in the section you've diagnosed as faulty. If you find a stage with dc voltages upset, you've located the faulty one. (One thing about this: if several transistor stages are dc coupled, the first one you measure may not be the truly bad one. You may have to "inject" dc voltages at strategic points to find out which stage is causing the trouble.

isolating the circuit

The third step of 1-2-3-4 Servicing is *isolating* the defective circuit. You may have done it already with some of your locating procedures.

For example, you may have traced a signal in a receiver as far as the collector of one stage but find it missing at the base of the next. You've located the faulty stage or stages; but, what's more, you've also isolated the faulty circuit. It's the circuit between the collector of one stage and the base of the next. That can only be the coupling circuit.

But even if you have no idea what circuit is bad, you have only a few to test. That's because you've eliminated those in other stages and sections by the first two steps. You now have to test only the circuits in one or at most two stages.

Signal tracing or injection both work for input, output, and coupling circuits. You can try adjusting tuned circuits; if they don't respond, they must be faulty. You can put a signal across decoupling and bypass circuits; the signal should be almost wiped out. Or, you can measure signal across them; it should be near zero.

You can use dc voltage tests. In a tube stage, you measure voltages in the plate, screen, grid, and cathode circuits. Keep in mind as you do that the grid affects all those others. If the voltages all are wrong, check for a problem in the grid circuit.

table 1. Basic steps to thinking 1-2-3-4 in servicing electronic equipment.

step	action	division
1	diagnose	sections
2	locate	stages
3	isolate	circuits
4	pinpoint	parts

In a transistor stage, the collector, base, and emitter dc circuits are the ones to check voltages in. Remember that the base controls collector voltage through its influence on current through the transistor.

If the transistor is a field-effect type, the voltages to measure are at the drain, the source, and the gate. The gate affects the drain voltage through its control on current through the channel.

pinning down trouble

The fourth and final step in 1-2-3-4 Servicing is *pinpointing* the faulty part. The job has by now been simplified almost to the point of no effort. Once you have the faulty circuit isolated, there are very few parts to think about. Even if you aren't sure which of two circuits is bad, the number of parts is small.

You can extend the tests you used in step three. You can make signal and dc tests that pinpoint the faulty part. You may have already done so during step three. For example, when you isolated the faulty coupling circuit, there's only one part so it's the bad one. That happens with other circuits, too.

But there are so few parts involved in this final step of 1-2-3-4 Servicing, you can freely succumb to individual parts tests. You've gained so much efficiency through the first three steps, this may be the quickest way to finish up. You can test most parts with your voltmeter or ohmmeter. (If you don't know how, I can tell you in a later repair bench.) Or, if you have a resistor-capacitor tester, a transistor tester, etc., use them.

Another fast way to test ordinary parts is by substitution. You can probably find what you need in your junk box.

table 2. Steps for 1-2-3-4 servicing.

DIAGNOSE (section)	A. Know the equipment	1. The schematic 2. Instruction manuals 3. Experience 4. Study books
	B. Inspect — Inside and out — Off and operating	1. Look 2. Listen 3. Smell 4. Feel
	C. Observe symptoms	1. Dead? 2. Works in part? 3. Operating controls? 4. Service adjustments?
LOCATE (stage)	A. Observe symptoms	1. Dead or operating poorly 2. Controls and adjustments
	B. Signal tests	1. Injection — Signal generators — Finger (tubes only) — From similar set
	C. Voltage tests	2. Tracing — Oscilloscope — Vtvm and probe — Signal tracer
ISOLATE (circuit)	A. Signal tests	1. Input circuit 2. Output circuit 3. Bypass circuits 4. Tuned circuits 5. Feedback circuits
	B. Dc voltage tests	1. Tube — Plate } Grid affects these — Screen — Cathode — Grid 2. Bipolar transistor — Collector — Base — Emitter 3. Field-effect transistor — Drain — Gate — Source
PINPOINT (part)	A. Signal tests (parts in signal circuits)	1. Tracing 2. Injection
	B. Dc voltage tests	1. In-line voltage tests (Use Ohm's and Kirchhoff's laws) 2. Tests in nearby circuits (For parts connected between) 3. Remember interaction — Grid affects plate, screen, cathode — Base affects collector and emitter — Gate affects drain and source
	C. Individual parts tests	1. With special testers 2. With volts and ohms tests
	D. Substitution	(Limit to common, inexpensive parts)

Or, some manufacturers make substitution testers (**fig. 4**) that include capacitors and resistors of many values, some diodes, some electrolytics, and so on. Except for expensive parts, substitution is a good bet, even if you have to keep a small stock of typical values.

fig. 4. Commercially built parts substitutor saves carrying an inventory of small parts for test purposes.

summing up

Now you can understand the chart in **table 1.** If you looked at it before reading how to apply 1-2-3-4 Servicing, it may not have made much sense. But it summarizes the steps of 1-2-3-4 Servicing as you apply them to troubles in your own equipment.

There's nothing mysterious about this method. If you're really efficient at finding trouble that occurs in your gear, you probably already use some version of this technique. If not, however, this logical approach can make troubleshooting easier than you ever thought possible.

To jog your memory for the method and how to apply it, you may want to cut out or copy the more complete chart in **table 2.** It gives you a thorough outline of the whole process and the means by which you can accomplish it. With it, you can apply 1-2-3-4 Servicing to any piece of ham gear you own.

next time . . .

Speaking of letters from you readers, I've really got a lot of them about using a sweep generator down in the low frequencies. In the very next *repair bench* I'll tell you how.

To get ready for it, I suggest you go back and review the earlier one about using a sweep generator and scope. I won't repeat much of the general information that tells how to set up the generator and scope for sweep alignment. That way, I spend most of my next *repair bench* explaining the techniques of sweeping at low frequencies and how to make use of it.

(Which all reminds me to remind you: If you have any other special ham repair problems you want covered in this department, it takes a letter to let me know.)

ham radio

adding incremental tuning to your transceiver

This simple varactor-controlled circuit can be added to any transceiver to provide the operating benefits of incremental tuning

Michael J. Goldstein, VE3GFN, 22 Kingswood Road, Toronto 13, Ontario

There you are, sitting on 14040 kHz with your transceiver humming. You're waiting for a call from VU2JN, along with six-dozen other guys in the pileup. He's working them 2-kHz down from his transmitting frequency, and your dial hand has muscle fatigue from cranking back and forth – move down 2, give him a quick call, back up 2, listen . . . down again and call, etc. What you need is receiver incremental tuning; no problem with the little circuit shown here.

incremental tuning

What you want is a system where you can set your main tuning dial and leave it; then, by using an independent control, be able to vary operating frequency slightly to either side of the main-dial setting, either while receiving only (RIT), while transmitting only (ITT), or while both transmitting and receiving (IRTT). With these added features you can check the band around your main frequency, and return to the original frequency with the snap of a switch. If you want, you can move your QSO off a busy channel without losing the original channel setting, or listen to two QSOs without touching the main tuning dial. In fact, you can do all the things only the more expensive transceivers allow for.

Let's look at what is involved as far as including incremental tuning in your transceiver. A typical oscillator tank circuit is shown in fig. 1. After L1 and C1 have been set for the desired frequency limits of the oscillator, capacitor C2 is used to adjust output frequency. Therefore, C2, which is connected to the main tuning dial, is used to control the receiving and transmitting frequency of the transceiver.

incremental tuning circuits

If you put a small variable capacitor (typically 10 pF) across the tank circuit as shown by the dotted lines in **fig. 1** (C3), set this additional capacitor at half mesh, and adjust the oscillator for the proper frequency limits, the circuit would operate exactly as before, with one exception: after setting the main tuning dial, the operating frequency could be varied slightly to either side of the main dial setting with C3. When C3 was returned to the half-mesh position, the operating frequency would be restored to the main-dial setting.

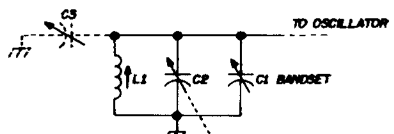


fig. 1. Simple, though impractical, incremental-tuning scheme uses added trimmer capacitor C3 across the vfo tank circuit.

However, although this is a simple way of obtaining incremental tuning, it is impractical. The same job can be done much more conveniently with a variable-capacitance diode or varactor. The varactor diode is essentially a variable capacitor that is controlled by a dc voltage instead of a rotating mechanical shaft. The capacitance range of these diodes, when operated over their rated voltage range, can be greater than 100 pF. If a 100-pF varactor was installed across the oscillator tank circuit, the result would be the same as an extra bandset capacitor, However, the effect on frequency change would be far too great.

This small problem can be solved by placing the varactor in series with a small trimmer capacitor as shown in **fig. 2.** The trimmer capacitor is then used to control the amount of effect diode capacitance has on oscillator frequency. If you use a 10-pF trimmer, and a 200-pF varactor, the maximum capacitance added to the tank circuit can be no greater than 10 pF.

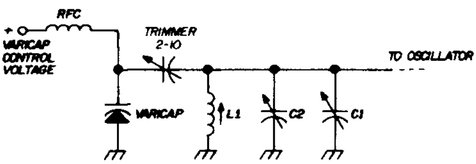


fig. 2. Varactor diode in place of C3 in fig. 1 provides practical means of obtaining incremental tuning.

transceiver modification

To incorporate incremental tuning in your own transceiver, locate the bandspread and bandset tuning capacitors. Then install the varactor diode, trimmer capacitor and rf choke as shown in **fig. 2.** Make sure the new components are mechanically rigid – you don't want to add instability to your transceiver's output frequency.

When soldering the diode into the circuit, protect it with heat sinks on the leads. Also, when installing the diode, make sure the anode of the varactor is grounded; the device must be reverse biased to operate correctly. The cathode end of the diode is usually marked with a white ring.

When all the components have been installed and checked, adjust the varactor bias voltage slightly more negative than the center of the recommended operating voltage range. This will lower the oscillator frequency slightly, so you must adjust the bandset capacitor to re-establish main dial calibration. *Do not* touch the oscillator coil.

change of frequency with rotation; use a high-quality potentiometer to eliminate problems with noise and frequency instability.

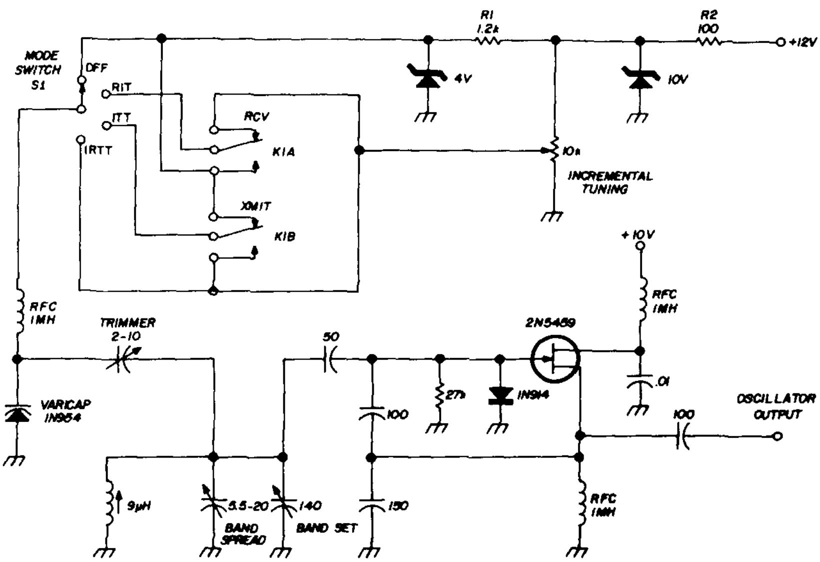


fig. 3. Complete incremental tuning circuit, as added to a 5.0 to 5.5 MHz vfo. Resistors R1 and R2 must be calculated for proper voltage drops if B+ is greater than 12 volts. Relay K1 is shown in the receive position; it must be switched with the antenna-change-over relay. With S1 in position 1, incremental tuning is off; position two, receiver incremental tuning; position three, transmitter incremental tuning; position four, receiver and transmitter incremental tuning.

The varactor's change of capacitance with voltage is not a linear function, so the "mid-point voltage" must be on the low side of the diode's voltage range mid-point, i. e., 4 volts for a zero to 10-volt varactor. Also, since the mid-point voltage of the varactor is used as a reference level for re-calibrating your main tuning dial, the bias source should be zener regulated as shown in **fig. 3.** This is especially important, because any change in transceiver operating voltages will effect the output frequency.

The complete incremental-tuning circuit, with all regulation and control circuits, is shown in **fig. 3.** This is the circuit for a 5.0 to 5.5 MHz solid-state oscillator that I used to test this incremental tuning scheme. The potentiometer in the circuit should be a *linear* type to provide a linear

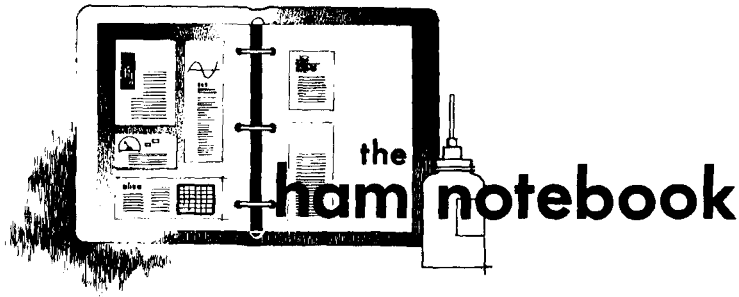
alignment

Vary the varactor bias voltage across its full range and see how much frequency variation you get. A total of 10 kHz is ideal. If you get too much variation, decrease the series trimmer capacitance; if you don't have enough variation, increase trimmer capacitance. Each time you change the trimmer setting you must reset main-dial calibration with the bandset capacitor.

By alternately adjusting the trimmer and bandset capacitors, you can obtain the amount of incremental tuning you want, while retaining main-dial calibration. A digital frequency counter makes this adjustment very easy, but a BC-221 or external calibrated vfo will work as well.

ham radio

More Details? CHECK—OFF Page 94



seconds; this increases accuracy since it permits easier timing.

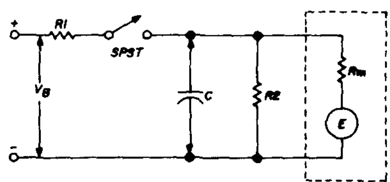


fig. 1. Circuit for determining capacitance of electrolytic capacitors. After measuring discharge time as discussed in text, capacitance can be found from nomograph in fig. 2.

measurement of electrolytic capacitors

Recently I had occasion to measure the value of an electrolytic capacitor. Since test equipment was not available, I devised a simple method using a resistor, a voltmeter and a stop watch. The capacitor was connected as shown in **fig. 1.**

The switch should remain closed for several minutes before making the measurement. This permits the electrolytic to form and stabilize. This is particularly important if the capacitor has been out of use for a long time. Resistor R1 is included in the circuit to limit the initial surge in charging current; its value can be on the order of 1000 to 5000 ohms.

When the switch is closed, read the voltmeter. Make a note of this reading (V_B). Now, mark the voltmeter at half this reading. This can be done by simply laying a strip of paper over the voltmeter scale at the $0.5V_B$ point. With a stop watch or watch with a sweep second hand, starting with the instant the switch is opened, measure the time required for the voltage to drop to the $0.5V_B$ point. Resistor R2 should be adjusted to produce a discharge time in excess of 30 seconds; this increases accuracy since it permits easier timing.

The value of the capacitor can be calculated from the following equation

$$C = 1.44\ (t/R) \qquad (1)$$

where t is in seconds, R in megohms, and C in microfarads (see **fig. 2**). The value of R in **eq. 1** is the parallel equivalent of R2 and R_M, the internal resistance of the meter (**eq. 2**).

$$R = \frac{R2\ R_M}{R2 + R_M} \qquad (2)$$

The resistance of a voltmeter is usually given in terms of "ohms per volt." If, for example, your voltmeter is rated at 20,000 ohms per volt, when set on the 100-volt scale R_M is 2 megohms (100 volts x 20,000 ohms = 2 megohms). Since R2 may be on the order of 1 megohm, voltmeter resistance cannot be neglected if you want accurate results.

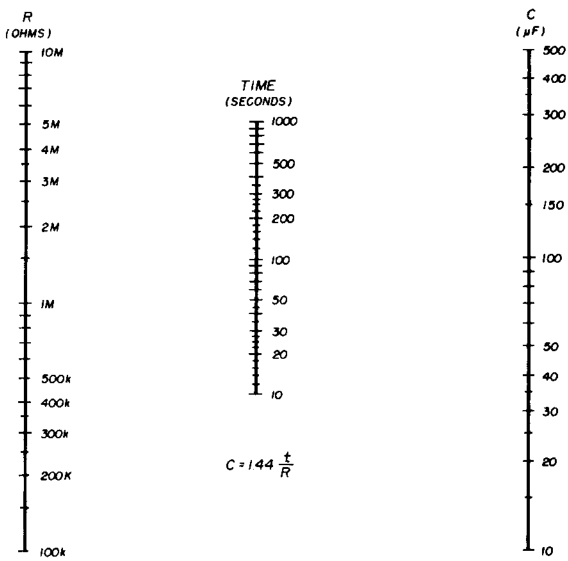


fig. 2. Nomograph for determining capacitance of electrolytic capacitors using method discussed in text.

Although this method of measuring capacitance can be used with any type of capacitor, on small-value units it's difficult to measure discharge time accurately enough to obtain meaningful results.

Edwin L. Clark, W2NA

blower maintenance

Many items of electronic equipment have blowers that move air across heat-generating components. The squirrel-cage blower seems to be popular in transmitters and transceivers, probably because these blowers are relatively quiet. Over a period of time, however, dirt builds up on the impeller in squirrel-cage blowers. Blower efficiency can gradually deteriorate without your being aware of it if dirt is allowed to accumulate. The result can be disastrous, especially if the blower is used to cool high-power transmitting tubes.

One remedy is to inspect the blower periodically and remove the impeller to give it a good cleaning. This usually involves considerable work, especially if the blower is located in an inaccessible place. Here's an effective preventive maintenance measure that not only keeps dirt buildup to a minimum, but eliminates the chore of removing the blower impeller for cleaning.

The intake port for the blower on my transceiver, a National NCX1000, is on the rear of the cabinet and flush with the vertical surface of the rear wall. After several hours of operation, I noticed that the blower impeller vanes were loaded with dirt. I used an old toothbrush to remove most of the grime, but it was necessary to remove the impeller from the blower to do a good cleaning job.

The answer to the problem consisted of a filter made from a piece of polyurethane foam about ¼-inch thick, which I cut to cover the blower intake port. Poly foam is available at retail sources that supply material for do-it-yourself furniture makers. It's used for filling seat cushions, and is available in several thicknesses. I secured the filter over the blower intake port with masking tape so it could be removed easily for cleaning.

Some types of poly foam have a more dense structure than others, so it's a good idea to test the filter before taping it into place. If the blower speed decreases appreciably, the foam is either too dense or too thick. A little experimentation will produce the right combination for effective filtering consistent with maximum blower efficiency.

I checked my blower and filter after about 90 hours of operation. The outside of the filter was coated with a rather thick deposit of dirt, but the impeller and blower housing were spotless. It was a simple job to remove the foam filter and wash it in warm water and detergent. The entire operation took about ten minutes, and the filter can be used indefinitely.

Alf Wilson, W6NIF

binding 1970 issues of ham radio

Many readers make their copies of *ham radio* into a bound volume each year. They will perhaps be surprised to note that the January and February 1970 issues are a little larger (8½ x 9½ inches) than from March 1970 on (6-1/8 x 9-1/8 inches).

Fortunately, there is no real problem. The actual printed portion of each page was left unchanged when the page size was reduced. The borders were merely narrowed. Thus, it is an easy matter to have a local printer retrim the two early issues to the new size and proceed with the binding.

The publishers of *ham radio* will be doing the same with the 1970 bound volumes which they produce.

Skip Tenney, W1NLB

improved power supply

Miniaturized power supplies for small-signal solid-state devices often present special problems, including heat reduction and adequate filtering within a limited space.

If an indicator light is necessary, an incandescent lamp across a secondary winding may be detrimental to the available rectified power output since the filament often dissipates a sizeable percentage of a small transformer's output. A 1/25-watt NE-2 neon indicator across the transformer primary will reduce heat as well as providing additional power for the load.

When a filter reactor or resistor is used in a conventional filter, both negative and positive excursions of the ripple voltage at the first capacitor are transferred to a degree to the second filter capacitor, and hence, to the load. Filtering may be improved by replacing the filter reactor or resistor with a garden variety power diode, D1, as shown in **fig. 3.** In this application D1 performs a gating function, allowing only the positive ripple components to reach C2, resulting in smoother filtering. If a heat-producing series resistor is replaced with the diode, cooler supply operation will result, although ripple will increase slightly.

Also shown in **fig. 3** is a simple method for supplying both + and − voltages from one transformer. This arrangment is useful for powering operational amplifiers, cascode circuits and digital devices requiring both polarities.

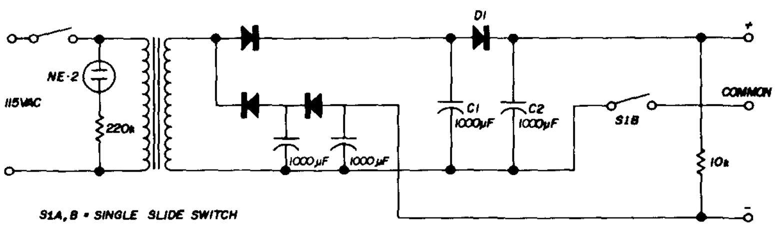


fig. 3. Improved power-supply circuit.

Gene Brizendine, W4ATE

grid dipping transmission lines

Most amateurs are familiar with the many uses of the grid-dip oscillator. If a gdo is coupled to a tuned circuit made of lumped constants (fig. **4A**), the meter will show a dip at resonance. Similarly, a gdo coupled to a circuit composed of distributed constants, such as a half-wave antenna (**fig.** 4B) or a half-wave section of transmission line (**fig. 4C**), the meter will dip at the resonant frequency of the antenna or transmission line.

The lowest frequency at which the gdo gives an indication of resonance is at a half-wavelength in the case of a Hertz or dipole antenna. When grid-dipping transmission lines, a propagation-velocity factor must be used. This factor is 0.82 for typical TV twinlead and 0.66 for commonly used coax cable (figs. 4C and 4D).

When grid-dipping antennas or sections of transmission lines, either of two methods may be used. The usual method

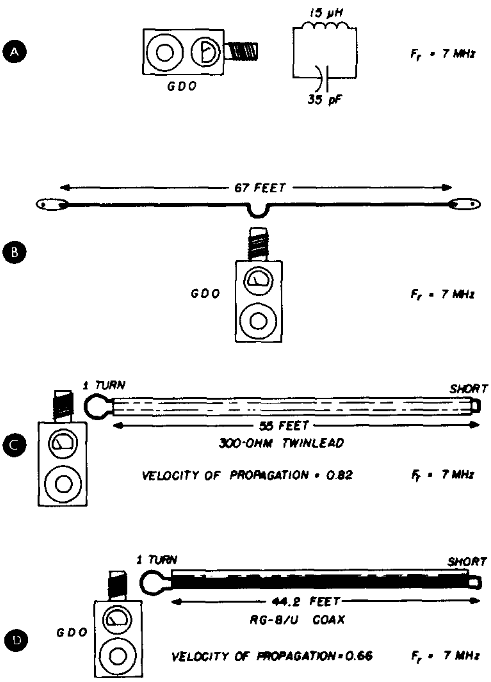


fig. 4. Illustrating the use of the grid-dip oscillator for determining resonant frequency of circuits with lumped and distributed LC constants.

is to determine the lowest frequency of resonance. If this isn't possible, you can grid-dip the line at several frequencies; i. e., at 4, 8, 12, and 16 MHz. A halfwave antenna has a "harmonic family" of resonances, roughly speaking, so you can expect similar behavior from a similar section of transmission line.

coiled transmission lines

Some hams roll up sections of transmission line for compactness. This is where problems can occur. It's practicable to coil sections of coaxial cable, but this procedure isn't recommended for balances lines, such as twinlead.

I experienced some frustrating results with a gdo coupled to coiled twinlead. Normal response was obtained when the twinlead was unrolled from the spool; but with the twinlead rolled up, gdo response was baffling. I obtained a series of minor and major dips, none of which seemed to produce a sensible pattern. When uncoiled, the twinlead behaved in normal fashion.

This anomaly may help to explain some rather odd reactions by those who have used twinlead for matching sections and, when coiling the line, have run into strange and unexpected results.

Neil Johnson, W2OLU

blower-to-chassis adapter

In many large rf power amplifiers it's not practical to mount the blower directly on the chassis — because of either size or noise. The setup shown in **fig. 5** allows the blower to be remotely located. A small tin can with both ends removed is soldered to a piece of printed-circuit board. The printed-circuit board is then mounted to the amplifier chassis with sheet-metal screws. A length of flexible hose is run from the blower to the adapter. The hose can be secured with a hose clamp or tape.

Bruce Clark, K6JYO

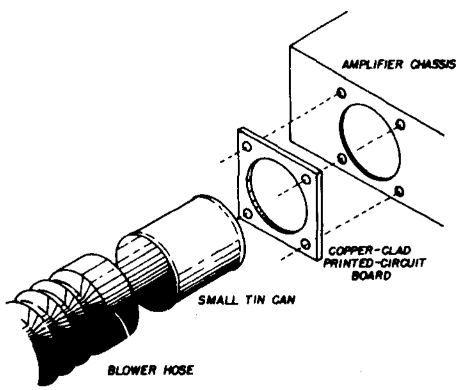
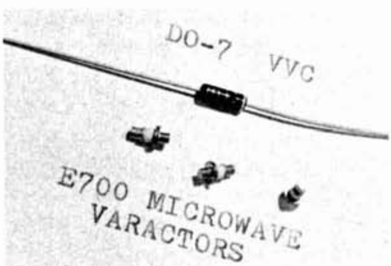


fig. 5. Low-cost blower-to-chassis adapter for high-power amplifiers. Use automobile hose clamp.

new products

amateur radio varactors



A new family of high-Q varactors for amateur radio applications has been announced by the Eastron Corporation. These new varactors offer performance characteristics suitable for operation from lower i-f frequencies up to 450 MHz. Typical uses include automatic frequency control, transceiver incremental tuning, remote control and simplified frequency modulation. These varactors are particularly useful for replacing complex mechanical tuning in compact electronic gear.

Prices range from $1.50 to $6.50 in small quantities. Application notes and data sheets are available from the manufacturer. Write to Eastron Corporation, 25 Locust Street, Haverhill, Massachusetts 01830, or use *check-off* on page 94.

national receiver

National Radio Company's new HRO-600 communications receiver is a high-performance, solid-state receiving system which permits a heretofore unattainable flexibility. The systems concept allows a user to custom-tailor a receiving system to his specific needs at the lowest cost consistent with his requirements. The HRO-600 receiving system consists of a main frame, choice of three frequency control plug-ins, and a large selection of useful accessories.

The main frame contains all receiver signal path circuits from antenna inputs through line and speaker audio outputs. These circuits include an antenna attenuator, slot filter assemblies, frequency converters, i-f amplifiers, i-f filters, a-m and product detectors, and audio amplifiers. It also includes a frequency synthesizer for first mixer injection, a beat-frequency oscillator, and a 115-230 volt 47-420 Hz power supply.

When the main frame is augmented by one of the frequency-control plugins, the receiver is capable of operating at any frequency between 10 kHz and 30 MHz in the following reception modes: a-m, cw, ssb, fsk and fax. Fsk operation also requires an accessory plug-in fsk converter or external audio equipment. Fax reception requires external audio equipment.

Other accessories available for the NRCI HRO-600 include a noise blanker, diversity combiner, remote-control system, dc power supply, vlf/mf/hf preselector, and independent sideband adapter.

For more information on this new receiver, write to National Radio Company, Inc., 111 Washington Street, Melrose, Massachusetts 02176, or use *check-off* on page 94.

hallicrafter fm two-way radios

The Hallicrafters Company has announced two new two-way fm radios that cover the amateur two-meter band as well as the 150-MHz business band; total frequency coverage is from 132 to 174 MHz.

The *Porta-Command* PC-210 is a ten-watt unit which, when combined with quick-change accessories, permits the operator to switch from portable to under-the-dash mobile or base-station operation. Output is from two to ten watts, selectable; hum and noise level is −50 dB minimum; spurious outputs are down 53 dB at 10 watts (46 dB at two watts); power supply voltage is 12 volts dc nominal. The receiver in the PC-210 is a crystal-controlled dual-conversion superhet that features sensitivity of 0.5 μV for 20-dB quieting; spurious and image response is −65 dB minimum; audio output is 1 watt into an 8-ohm speaker. Accessories include battery pack, continuous-tone squelch, ac power tray, battery charger, and back-pack or shoulder carrying case.

The *Porta-Command* PC-230 is a 30-watt solid-state radio that weighs only five pounds and takes up less than 250 cubic inches of space. The unit provides up to 12 channels across 1 MHz with no power loss and is instantly adaptable with accessories to mobile, base-station or manpack operation. Power output of the PC-230 is 30 watts; current drain is less than 15 mA on standby, 5.5 amps on transmit; designed for continuous transmit, 100% duty cycle; 132 to 174 MHz frequency coverage. The receiver features sensitivity of less than 0.5 μV for 20-dB quieting; hum and noise are better than 50 dB down from rated output. Accessories include ac power tray, continuous-tone squelch, mobile mounting rack and various antennas.

Illustrated brochures that describe each of these fm sets are available from The Hallicrafters Company, FM 2-Way Department, PR, 600 Hicks Road, Rolling Meadows, Illinois 60008, or use *check-off* on page 94.

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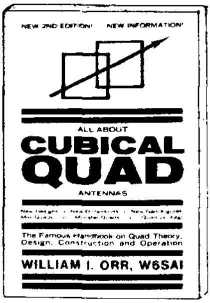

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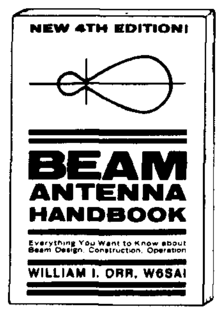

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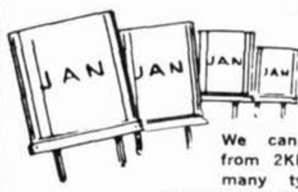

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Modulation	Phase Modulation with automatic deviation limiting
Deviation	Automatic Limiting with internal adjustments from 0-15KC deviation
Microphone	Plug-in, hand held, high Z Ceramic supplied
Channels	6 Crystal controlled with individual trimmer capacitors for Frequency netting

GENERAL

Power Requirements	13.6 Volts (nominal)
Receive (Squelched)	180 MA.
Receive (Max. audio output)	800 MA.
Transmit	2.5 Amps (max.)

STANDARD EQUIPMENT

Built-in 4″ Speaker
Mobile Mounting Bracket
SO-239 Antenna Connector Socket
T & R Crystals for 146.94 MHz
PTT Ceramic Mike

only $229.00 Amateur Net

Regency **ELECTRONICS, INC.**

7900 Pendleton Pike, Indianapolis, Indiana 46226

This is actual size and shape of our radio. Cut it out and place it under your dash to see how compactly it fits.

More Details? CHECK—OFF Page 94

flea market

■ **RATES** Commercial Ads 25¢ per word; non-commercial ads 10¢ per word payable in advance. No cash discounts or agency commissions allowed.

■ **COPY** No special layout or arrangements available. Material should be typewritten or clearly printed and must include full name and address. We reserve the right to reject unsuitable copy. **Ham Radio** *can not check out each advertiser* and thus cannot be held responsible for claims made. Liability for correctness of material limited to corrected ad in next available issue. Deadline is 15th of second preceding month.

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

"HOSS TRADER ED MOORY" says he will not be undersold on Cash Deals! SHOP around for your best price and then call or write the "HOSS" before you buy! NEW EQUIPMENT: New Demo Galaxy GT-550 with warranty, $389.00: New Swan 270B Cygnet, $399.00 freight prepaid: New Swan 500CX, $449.00 freight prepaid with Free Electro Voice Microphone: New Rohn 50 Ft. Foldover Tower prepaid, $213.00: New Mosley Classic 33 and Demo Ham-M Rotor, $205. RECONDITIONED EQUIPMENT: Drake TR-4, (late serial), $519.00: T4-XB, $365.00: R4-B, $349.00: Ham-M Rotor, $79.00. No reasonable offer on new equipment refused! Try Me! Moory Electronics Co., P. O. Box 506, Dewitt, Arkansas 72042. Phone (501) 946-2820.

SURPLUS MILITARY RADIOS, Electronics, Radar Parts, tons of material for the ham, free catalogue available. Sabre Industries, 1370 Sargent Ave., Winnipeg 21, Manitoba, Canada.

THE 20th ANNIVERSARY DAYTON HAMVENTION will be held on April 24, 1971 at Wampler's Dayton Harra Arena. Technical sessions, exhibits, hidden transmitter hunt and an interesting program for the XYL. For information write Dayton Hamvention, Dept. H, Box 44, Dayton, Ohio 45401.

MICHIGAN — 24,000 square ft. for the Blossomland Amateur Radio Association 4th annual auction and Swap-Shop at Shadowland Ballroom, St. Joseph-Benton Harbor, Mich. Sunday, March 14th 9:00 a.m. to 4:00 p.m. Hot food. Prefer to do your own selling? Rent one of our swap tables. If that fails let our skilled auctioneer put your gear on the block. Direct inquiries to B.A.R.A., Box 175, St. Joseph, Michigan 49085.

HEATH SB-310 receiver, mint, professionally aligned, deluxe SSB crystal, plug in crystal for 15M novice band, $235.00, WB9DVV, 335 North Elmwood Lane, Palatine, Illinois 60067.

TELETYPE #28 LRXB4 reperforator-transmitter "as is" $100; checked out $175. Includes two 3-speed gearshifts. Alltronics-Howard Co., Box 19, Boston, Mass. 02101. 617-742-0048.

THE NOVICE newsletter. **Free sample,** 1240 21st Street, Hermosa Beach, California 90254.

GREENE — center of dipole insulator with . . . or . . . without balun . . . also the GREENE DRAGON FLY antenna . . . send for free flier . . . GREENE, Box 423, Wakefield, R. I. 02880. W1CPI.

SWAPFEST National Guard Armory, St. George, S.C., Sunday, February 7, 10:00 a.m. - 4:00 p.m. Talk-in 3950 SSB - 146.94 FM. "Hoss trading", Displays, Prizes. Bring all your gear for sale. Please let us know in advance how many to seat, number of tables, etc. Write Chamber of Commerce, Box 348, St. George, S.C. 29477 or call W4DTW, 803-563-4377.

826 TUBES wanted for cash. C. Hutnan, 308 Hickory Street, Kearny, N. J. 07032.

"DON AND BOB" guaranteed new buys. Monarch KW SWR Relative power dualmeter bridge, was 15.95, now 14.95. Hygain TH6DXX 139.00; Hyquad 104.00; Mosley Classic 36 134.00; Ham-M 99.00; TR-44 59.95; Regency HR2 2M. FM (reg. 229.00) $195.00; Motorola HEP170 epoxy diode 2.5A/1000 PIV 39¢; Amperex 8802/3-500Z 32.00; 6146B 4.45; 6LQ6 3.50; write quote Drake SPR-4. Prices FOB Houston. GECC finance. Madison Electronics, 1508 McKinney, Houston, Texas 77002. (713) 224-2668.

SAVE. On all makes of new and used equipment. Write or call Bob Grimes, 89 Aspen Road, Swampscott, Massachusetts, 617-598-2530 *for the gear u* want at the prices u want to pay.

GALAXY FM210, AC supply $195. John Stiles, K7DGV, Sweetgrass, Montana 59484.

ELECTRONICS YOUR BAG? Looking for an electronics course . . . that you can pay for by the subject AND take ONLY the subjects you NEED? . . . that you can change into ANY PHASE of electronics after completion of basics WITH NO PENALTY? For full information, write: EDCO ENTERPRISES INC., P. O. Box 432, Sparks, Nev. 89431.

NOVICE CRYSTALS: 40-15M $1.38, 80M $1.83. Free flyer. Nat Stinnette Electronics, Umatilla, Florida 32784.

THE TEXAS VHF-FM SOCIETY will hold its semi-annual convention February 26, 27 and 28, 1971. All Southwest amateurs interested in the technical aspects of repeater construction and operation are invited. Among other attractions will be a special program for XYL's and Jr. Ops., a family dinner, new equipment exhibits and prizes. Manufacturers of specialty items of use to serious VHF-FM operator, are urged to contact the hosting organization about participation. Arrangements have been made for pre-registration at the El Tropicano Hotel, site of the convention. All interested parties write for a pre-registration package. San Antonio Repeater Organization, P. O. Box 1753, San Antonio, Texas 78206.

QSLS. Second to none. Same day service. Samples 25¢. Ray, K7HLR, Box 331, Clearfield, Utah 84015.

TOROIDS 44 and 88 mhy. Unpotted, 5 for **$1.50** ppd. W. Weinschenker, Box 353, Irwin, Pa. 15642.

WORLD QSL BUREAU — See ad page 92.

SYRACUSE, NY HAMFEST — April 17, at Song Mountain off Interstate 81, exit 14. Flea Market, contests, speakers, nets. R.A.G.S., Box 88, Liverpool, NY 13088.

THE LAKE COUNTY Amateur Radio Club, Inc., Gary, Indiana, proudly announces its 18th Annual Banquet to be held at 6:30 p.m., CST, on February 20, 1971. Location: Teibel's Restaurant at the corner of U.S. 30 and U.S. 41, Schererville, Indiana. *Chicken dinner, entertainment, awards and fellowship.* Come! Bring your wife or girl friend. Tickets are $5.00 each from Herbert S. Brier, W9EGQ, Ticket Chairman, 385 Johnson St., Gary, Indiana 46402, or from other club members. **Positively no tickets sold at the door!**

MECHANICAL FILTERS: 455 Khz. 2.1 Khz **$18.95.** 300 Hz $22.95. J. A. Fredericks, 314 South 13th Avenue, Yakima, Washington 98902.

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Western Electric 1500 mfd. @ 25 volt Electrolytic Capacitor. Axial leads 2 for $1.00 ppd

1N4007 1000 V PIV 1 A Silicon diode 28¢ ea ppd

500 MFD @ 50 Volt Electrolytic capacitors Axial Leads 40¢ ea ppd

General Purpose Germanium diodes similar 1N34A 25 for $1.00 100 for $3.00 1000 for $20.00 ppd

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50 V PIV Top-Hat diodes 33 for $1.00 ppd

3000 MFD @ 16V Electrolytic 2 for $1.00 ppd

3ACP11A CRT Tubes New Boxed $4.90 ea ppd

Assorted Carbon Resistors 100 for $3.00 ppd

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Boonton 202D-175-250mHz sig gen	325
Boonton 207E-Univertor for sig gen	110
GR736 A-Wave analyzer	249
GR821A-Twin-T Imp. bridge	235
GR1603A-Z-Y bridge	176
Gertsch FM3/PS3 20-1000MHz freq mtr	275
HP120AR-200kHz scope	135
HP175A-50mHz scope-main frame only	450
HP524B-10mMz freq counter	495
HP525A-10-100mMz plug-in for above	115
HP525B-100-220mMz plug-in for above	135
HP525C-100-500mMz plug-in for above	225
HP526B-Time interval plug-in for above	65
HP608A-10-500mHz stand sig gen	400
Meas 65B-75kHz-30mMz sig gen	325
Meas 82-20Hz-200kHz, 80kHz-50mMz stand sig gen	275
NE Eng 14-20C-10mHz freq counter (as is less time standard)	180
NE Eng 14-20C-complete, checked	295
NE Eng 14-21C-10-10mHz conv for abv	114
NE Eng 14-22C-100-220mMz conv for abv	135
NE Eng 14-24C-Time interval conv for abv	65
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Tektronix 517A-Hi-speed scope	545
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USM24C-8mHz time ba-e scope	125
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USM105A-Mil version HP160 scope w/dual trace plug-in	550
ZM-11-Capacitance bridge	80

(Send SASE for complete list)

GRAY Electronics
P. O. Box 941 Monroe, MI 48161
Specializing in used test equipment

More Details? CHECK—OFF Page 94

ROCHESTER, N. Y. will again be headquarters for the huge W.N.Y. Hamfest, V.H.F. Conference and Flea Market May 15, 1971.

ORIGINAL EZ-IN DOUBLE HOLDERS display 20 cards in plastic, 3 for $1.00, 10 for $3.00 prepaid. Guaranteed. Patented. Free sample to dealers. Tepabco, John K4NMT, Box 198R, Gallatin, Tenn. 37066.

FOR SALE: Squires-Sanders SS1R, SS1RS, SS1S, (all new), $550. HRO500, $850. 75S3B #85399, $550. KWM2A #18922, Noise Blanker, 516F2, $950. 75S1, 32S1, 516F2, $600. MP1, or 516E1, $100. 351D2, $100. 312B4: new, $175; used, $135. 30L1 #25752, $400. SR160, P150DC, $195. P500AC (for SR400/SR500), $75. SR150, P150AC, $275. 312B5, $275. SW500C, 117XC, mobile mount, $475. Galaxy 300, PSA300, $165. Waters Nuverter, $100. Viking Thunderbolt, $225. C. E. 100V, $235. Waters Hybrid Coupler, #3002, $40. Model 80 Signal Generator, $125. Motorola 80D, complete, $75. Capacitors, 4mfd/10KV, $15. Variac: 0-140V/20 amps, $25. Simpson #260 (factory-reconditioned), $45. Telex headset (new), $5. Lafayette HA750, HB502, mike, Squalo, $100. TA33 (new), $120. Filter F455Y60 (for 75S1/S2/S3), $20. TR44 (new), $60. Lambda VR supplies, write for details, $25. Messenger III, AC supply, $100. Transformers: 115/2880VCT @ 500 Ma, $15; 115/5VCT @ 30 amp, $8; UTC S49, $15; UTC S57, $4; UTC S60, $9; S63, $7. General Radio 1800A VTVM, $75. Millivac MV17C DC VTVM, $35. Ferris Microvolter, Model 20-A1, $50. Collins 302C3 wattmeter, $75. Waters Codax Keyer (as is), $25. HA-1, Vibrodeyer, $75. James W. Craig, W1FBG, 29 Sherburne Avenue, Portsmouth, N. H. 03801.

FLYING HAMS: Trade your excess gear for Avionics Equipment. All lines available in the box or installed in your aircraft. All fully warranted. Interested in all lab test equipment, ham or military type gear. Powell Avionics, FAA Repair Station #711-1, Box 106, Fayetteville, N. C. 28302. 919-484-0236, nite 483-9426.

SP600JX "super pro" receiver .54-54 mc guaranteed $175. Curt Powell, WA5PVB/4, R. F. D. 2, Box 267, Rocky Mount, N. C. 27801.

ASK FOR FREE LIST of used Ham gear or for prompt personal attention on any new gear. Mail your order direct to VanSickle Radio, W9KJF, Indianapolis, Indiana 46205. 40 years experience.

CODE PRACTICE TAPES - Novice - General - Extra Class - Specify - $8.00 each. W9CJJ, 1105 Schaumburg Road, Schaumburg, Illinois.

IRISH HOLIDAY exchanged for VHF, mobile, sideband gear. Stay in friendly guesthouse. Scenery, seasides, sports local. Des Walsh EI5CD, Carrick-on-Suir, Co. Tipperary, Ireland.

WANTED, 1968 Bound Volume of Ham Radio or April through December loose issues. Also need March and April 1970. Write Joseph Yu, 34 Grove Crescent, Kingston upon Thames, Surrey, England.

DRAFTING SERVICE — For Hams, Engineers - Professionally Inked - Ready For Publication - 20 Years Experience - Reasonable - For Information Send SASE - R. Wildman - 8512 Acapulco Way #2 - Stockton, California 95207.

MOTOROLA FM — 2 meters; U43GGT, 40 watts output, transistor supply, very clean, with cables and control head, less crystals - $145.00. 80D Transmitter strip - $15.00. Sensicon A Receiver - $20.00. Complete 80D, Dynamotor supply with cables and head - $40.00. WA1INO, P. O. Box 587, Manchester, Conn. 06040.

RADIO CONTROLLED GARAGE DOOR OPENER. Om's! Be kind to your XYL and your car. Now the car will be where it belongs; in the garage. Not a kit. Shipped ready for installation with easy to follow instructions. Write for free brochure and price information. You'll be pleasantly surprised. Radio Door Co., P. O. Box 282, Pomona, New York 10970.

450 MC 12 VOLT TRANSCEIVER all transistor 70 watt output built in PL tone 5 watt power speaker $225.00. WB2ROL, Joe Oley, 50 Old Oak Lane, Levittown, N. Y. 11756. U.S.A.

More Details? CHECK—OFF Page 94

THE WORLD WIDE VHF ACTIVITY starts March 6 at 1900 GMT, ends March 8 at 0300 GMT. BASIC RULES: 1. Any amateur bands above 30 Mhz. Exchange call letters, and area location. (State for US stations, Provinces for Canada, Country for all others). 2. SCORING: One point per contact regardless of band. Final score will be different area locations worked times total points. An area location worked on a new band for that location will count as a new area location. A recognition certificate will be awarded every ham station submitting a log that has met one of the following requirements: 50 contacts on any legal VHF band below 144 Mhz. **OR** 25 contacts on the 144 Mhz band. **OR** 20 contacts in the combined bands of operation above 148 Mhz. ALL CONTACTS MUST BE MADE DURING THE ACTIVITY PERIOD. SEPARATE AWARDS for high score will be awarded in each call area, Canadian Province or country. (Multiops separate.) Logs go to the Itchycoo Park VHF ARS, WA3NUL, P. O. Box 1062, Hagerstown, Md. 21740. Mailing deadline is APRIL 1, 1971. All automatic awards made in category one will be processed within 3 weeks of April 1 if the valid applicant encloses a 6¢ U.S. stamp or IRC to defray postage costs. All other awards will be mailed out, but precedence goes to those stations helping us with postage. WA3NUL.

DON'T BUY QSL CARDS from anyone until you see my free samples. Fast service. Economical prices. Little Print Shop, Box 9848, Austin, Texas 78757.

TOLEDO MOBILE RADIO Association's 16th Annual Hamfest and Auction will be held February 21, 1971, Lucas County Recreation Center, Maumee, Ohio. $1.00 Registration, open table sales. Map and info write: TMRA W8HHF, Box 273, Toledo, Ohio 43601.

TOROIDS! Lowest price anywhere. 40/$10.00 POSTPAID (5/$2.00). center tapped, 44 or 88mhy. 32KSR page printer, reconditioned, perfect $225. MITE UGC41KSR page printer, reconditioned, $250. Mod28 Sprocket to friction kit, $25. 28LBXD TD, $70. 28LPR reperf with gear shift, $170. Model 15KSR, $65. Matching RA87P.S. Unused, $7. Lorenz 15KSR, $75. Sync motors, $7. 14TD, $20. DPE punch, $14. HP200CD Oscillator, $95. R390/URR, $550. 11/16" tape, 40/$10.00. 33ASR, complete, $700. Stamp for listing. Van W2DLT, 302H Passaic, Stirling, N. J. 07980.

WANTED: RTTY activity on six meters. Any local amateurs on 6-meter RTTY please contact Bill Waggoner, 49 Roosevelt Blvd., Enfield, Conn. 06082.

BOOKS: Don't miss our ad on pages 48 and 49 Comtec.

WANTED R390, R390A, R389, 51J4, 51S1, Racal, Nems, Clarke, Marconi receivers. SWRC, P. O. Box 10048, Kansas City, Missouri 64111.

MANUALS — R-390/URR, R-390A/URR, BC-639A, URM-25D, CV-591A/URR, TS-497B/URR, FR-5/U, TS-587B/U, UPM-45, USM-24C, SP-600JX, $6.50 ea. S. Consalvo, 4905 Roanne Drive, Washington, DC 20021.

COLLINS 75-S1, 500 C.P.S. Filter $300; 32 S1 & 516 F2 Power Supply both $375; Phone 215 887-1232, Marty Shapiro, evenings only.

THE WHEATON COMMUNITY RADIO AMATEURS will hold their ninth annual Mid-Winter Swap and Shop on Sunday, February 21, 1971 at the DuPage County Fair Grounds, Wheaton, Illinois. Hours - 8:00 A.M. to 5:00 P.M. $1.00 Advance/$1.50 donation at the door. Send SASE for advanced tickets P. O. Box QSL, Wheaton, Illinois. Refreshments and unlimited parking. Bring your own tables. Free coffee and doughnuts 9:00 to 9:30 A.M. Hams, CBers, electronic hobbyists, friends and commercial exhibitors are cordially invited. Contact John Stockberger, W9THI, P. O. Box QSL, Wheaton, Illinois 60187 for information.

HEATH SB-301 excellent condition $225 prepaid. Wanted schematic and manual Hammarlund HK-1B Keyer. Will cover expenses. Cline WB6LXI, Box 4475, Santa Barbara, CA 93103.

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EFJ #512-504, dual, split stator, 37 to 305 pf/sec. 7KV(.175") spacing. Dual $\frac{1}{4}$" shafts. $5\frac{3}{4}$" w. x $5\frac{1}{2}$" h. x $16\frac{3}{4}$" l. + $2\frac{3}{4}$" for shafts. Has 40:1 right angle gear drive. 9 lbs. **4 for $31.00; each $8.00**

JOHNSON type R and HAMMARLUND type M
All with dual $\frac{1}{4}$" shafts.

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E #149-5, 7.1 to 102 pf. 1 KV. 1 lb. **4 for $4.25; each $1.10**

E #149-6, 8 to 140 pf. 1 KV. 1 lb. **4 for $4.75; each $1.25**

H #4111-8, 5 to 30 pf. 2 KV. 1 lb. **4 for $4.25; each $1.10**

H #MC-50M, 6 to 50 pf. 1 KV. 1 lb. **4 for $4.25; each $1.10**

5 to 20 pf. 3 plate. 1 KV. 1 lb. **4 for $3.00; each 79¢**

Dual, split stator, 5 to 27 pf/sec. 3 KV. **4 for $6.50; each $1.75**

Dual, split stator, 7 to 50 pf/sec. 2 KV. 2 lbs. **4 for $8.25; each $2.25**

CARDWELL, #56-7832, 35 to 1017 pf. $3\frac{1}{2}$ KV. $\frac{3}{8}$" single shaft. 6" x $3\frac{1}{2}$" x $12\frac{1}{2}$". 10 lbs. **4 for $28.00; each $7.50**

C 10 to 75 pf. 3 KV. single $\frac{1}{4}$" shaft. micalex insulation. **4 for $8.50; each $2.25**

C 10 to 85 pf. 3 KV. single $\frac{1}{4}$" shaft. 2 lbs. **4 for $8.50; each $2.25**

5 gang, 402 pf/sec. 600v. total 2010 pf. Ideal for output side of pi-net. Will handle 1 KW, to 160 meters, without inductance. 3 lbs. $\frac{3}{8}$" shaft. **each $3.00**

as above, but take-outs, good, clean, with rt. angle worm gear drive. **each $2.50**

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#160-130, 3 to 32 pf.; #160-211, butterfly, 2.7 to 10.8 pf.; #160-308, differential 2.3 to 14.2 pf. CHOICE, mix or match; **10/$8.00; 4/$3.25; each 89¢**

BC-453B, 190 to 550 KC, command receiver, with 3, 85 KC IF. with variable coupling. Complete with all tubes and internal parts. 12 lbs. **BRAND NEW. each $16.50**

All prices are NET, FOB store, Chicago. **PLEASE** include sufficient for postage. Any excess returned with order. All items subject to prior sale. Send S.A.S.E. for flyer.

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Complete reference library of maps — set of 4 as listed above . . . . postpaid **$3.50**

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up to 2 "S" units signal gain
WITHOUT A LINEAR ! ! ! !

NO CLIPPING — NO DISTORTION
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2415 S. Broadway, Santa Ana, CA 92707
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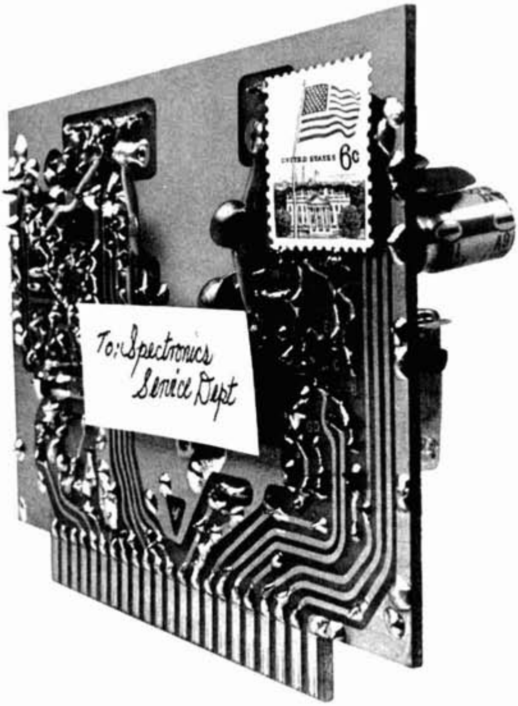
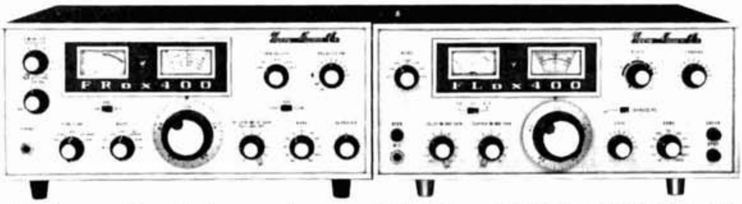


More Details? CHECK–OFF Page 94

Now you don't have to pay twice the price to get twice the rig.



Picture this pair in your shack. The Yaesu FLdx 400 transmitter and the FRdx 400 receiver. Loaded with power. Loaded with sensitivity. Loaded with features. Loaded with value. Read on, and discover how you can have the most up-to-date receiver-transmitter rig in the world . . . and at an unbelievably low price.

The FRdx 400 Receiver

Get a big ear on the world with complete amateur band coverage from 160 meters through 2 meters, including WWV and CB reception. Four mechanical filters do it — they provide CW, SSB, AM and FM selectivity. Separate AM-SSB-FM detectors are included, along with squelch and transmit monitor controls. Plus a noise limiter and a variable delay AGC. And a built-in notch filter with front panel adjust for notch depth.

The FRdx includes calibration markers at 100 KHz and 25 KHz, with accurate calibrator checks verified by WWV. A solid-state FET VFO for unshakable stability. And a direct-reading 1 KHz dial affords frequency read-out to less than 200 Hertz.

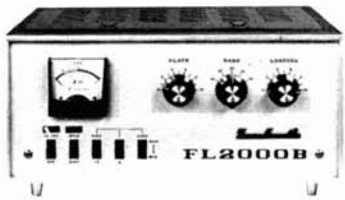
The FRdx 400 sells for $359.95.

The FLdx 400 Transmitter

Here's how to set yourself up with dual receive, transceive or split VFO operation. The FLdx 400 with its companion receiver brings you the ultimate in operational flexibility. Flexibility like frequency spotting, VOX, break-in CW, SSB, AM and even an optional FSK circuit.

The completely self-contained FLdx 400 features a built-in power supply, fully adjustable VOX, a mechanical SSB filter, metered ALC, IC and PO. A completely solid-state FET VFO provides rock-solid frequency stability.

We rate the FLdx 400 very conservatively. That rating guarantees you 240 W PEP input SSB, 120 W CW and 75 W AM. The FSK option will go all day at a continuous 75 W. And you get full frequency coverage on all amateur bands — 80 meters through 10 meters — with an optional provision for certain other bands that you can personally specify. For all that, you pay just $299.95.



FL2000 B Linear Amplifier.

Ideal companion to the Series 400, this hand-crafted linear is another example of Yaesu's unbeatable combination of high quality and low cost. Designed to operate at 1500 watts PEP SSB and 1000 watts CW, this unit provides superb regulation — achieved by a filter system with 28 UF effective capacity.

Other features include dual cooling fans (one for each tube), individual tuned input coils on each band for maximum efficiency and low distortion, and a final amplifier of the grounded grid type using two rugged carbon-plate 572 B tubes. Ready to operate at only $299.95.

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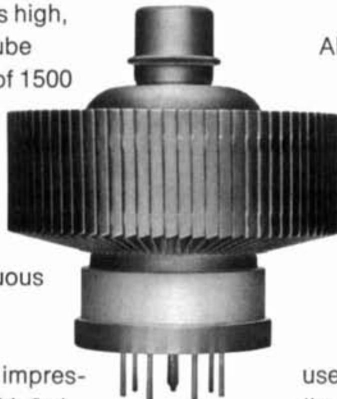
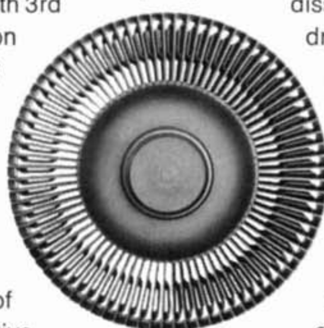
EIMAC's new 8877 high-mu triode delivers over 1500 watts output at 220 MHz. (2000 watts output at 30 MHz is easy)

On your right is the new, rugged, ceramic/metal 8877 high-mu power triode by EIMAC. Another state-of-the-art tube. Only three and one-half inches high, this low-profile, heavy-duty tube has a plate dissipation rating of 1500 watts, a maximum plate voltage rating of 4000 and a maximum plate current rating of one ampere. In the HF region, typically, the 8877 coasts along at a continuous duty level of 3500 watts PEP input. A peak drive signal of only 65 watts is required. This impressive power gain is achieved with 3rd order intermodulation distortion products −38 decibels below one tone of a two equal-tone drive signal.

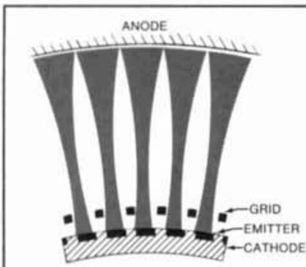
This magnificent power triode is rated at full input to 250 MHz. The low impedance grid structure is terminated in a contact ring about the base of the tube, permitting very effective intrastage isolation to be achieved up to the outer frequency limit of operation. The close tolerance grid, moreover, is composed of aligned, rectangular bars to achieve maximum grid dissipation and controlled transconductance. This aligned grid, plus the EIMAC segmented, self-focusing cathode provide low grid interception and the low grid drive requirement; both of paramount importance in the VHF region.





Although primarily designed for superlative linear amplifier service demanding low intermodulation distortion, the 8877's high efficiency permits effective operation as a class C power amplifier or oscillator, or as a plate modulated amplifier. The zero bias characteristic is useful for these services, as plate dissipation is held to a safe level if drive power fails, up to an anode potential of 3 kV.

The sophisticated circuit connoisseur will appreciate the many advantages of this newly developed power tube. Write for detailed information. And remember —the 8877 is another example of EIMAC's ability to provide tomorrow's power tube today. For additional information on this or other products, contact EIMAC, 301 Industrial Way, San Carlos, California 94070. Phone (415) 592-1221 (or call the nearest Varian/EIMAC Electron Tube and Device Group Sales Office.)



Parallel electron "guns" provide electron focusing, low intermodulation distortion, and low grid interception.

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