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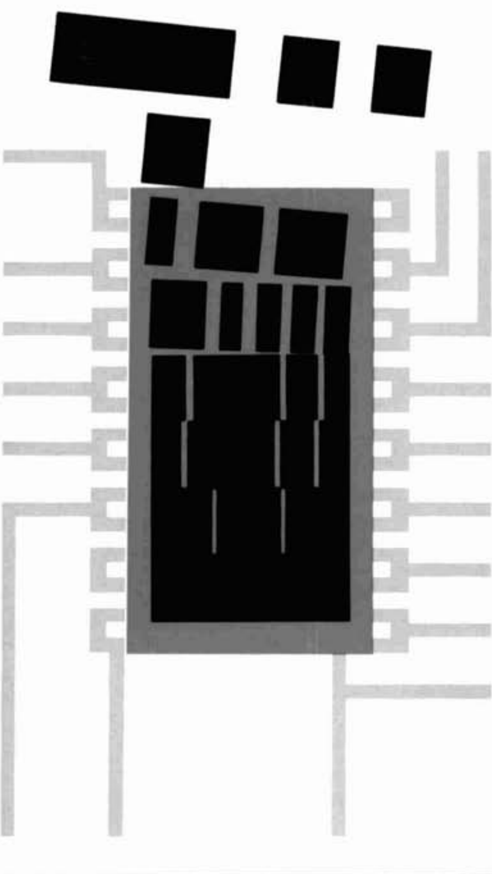
ham radio magazine

JANUARY 1974

cw memory
for RTTY identification



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More Details? CHECK—OFF Page 110

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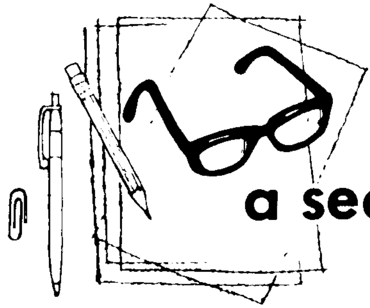

a second look

by jim fisk

More in '74. If you haven't seen that motto or heard of the concept, you will, because in 1974 *ham radio* will be providing a whole new family of services to the amateur community, services that will help each amateur derive the most enjoyment from his hobby.

More in '74 means a lot of things to *ham radio* readers, including more editorial staff and more specialized publications as well as some other exciting new projects. Since some of these projects are still in the embryonic planning stages we can't tell you much about them, because the final product may be considerably different than the original concept, but complete details will be announced as soon as they are available and those announcements will be well worth waiting for.

More in '74, among other things, means a new editor for *ham radio* and a new role for me as editor-in-chief. However, a change in editorial staff does not mean a shift in editorial policy. *Ham radio* will continue to do what we do best, bringing you the latest and best in technical articles and construction projects each and every month. The new editor, Joe Schroeder, W9JUV, has been an active amateur for more than 25 years and is well known to many of you. He's been associated with the electronics industry in one way or another for 20 years, was the editor of *Instrument Digest* and, more lately, editor of *Guns Illustrated.* Until leaving Chicago recently, he was on the Technical Committee of the Illinois Repeater Council. Joe is also an Honor Roll DXer with more than 340 countries to his credit and is active on all bands from 160 meters to 450 MHz. You'll be hearing a lot more from him in the future. Between the two of us *ham radio* will be bigger and better than ever.

More in '74 means a brand-new newsletter, *HR Report,* which will keep you up to date with late-breaking news from the FCC, ARRL and industry sources, new DX activities, contest and hamfest announcements and up-to-the-minute propagation forecasts. The first issue of *HR Report* will be available in early January and will be sent out to subscribers twice monthly via airmail after that. In addition, special issues will be published as events warrant. If you want to know what's happening in the amateur world, you owe it to yourself to subscribe to *HR Report.* The subscription rate in the United States and Canada is $12.00 per year ($15.00 for overseas readers) with a guaranteed minimum of 24 issues per year.

More in '74 means a number of other new publications including new titles for your bookshelf and new operating aids for your station. For example, a new *Novice Radio Guide* is presently in production and will be available within a few months. Volume II of the popular *Ham Notebook* is currently in preparation and will be available later this year as will several other new titles.

These are only a few of the highlights — more announcements will be made as we progress through the year.

Ham Radio . . . more in '74.

Jim Fisk, W1DTY
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CW memory

for RTTY identification

Complete construction details for the RM-100 — a 256-bit CW memory using modern read-only memory ICs

Howard L. Nurse, W6LLO, 665 Maybell Avenue, Palo Alto, California 94306

Do you find it frustrating to stop typing in the middle of an RTTY QSO to comply with FCC rule 97.87? This rule requires that you, as an RTTY station operator, keep your CW key at the ready to identify properly. The RATTline RM-100 CW memory is designed to facilitate that required CW identification.

The RM-100 uses an integrated-circuit memory to allow automatic CW transmission of a message at the speed of approximately ten words per minute. It can be connected directly to the RY-170 AFSK generator described in the December, 1973, issue of *ham radio* (see **fig. 1**), or to any other keying line compatible with the npn open-collector output of the RM-100.

When you want to identify, a CW message such as ". . . de W6LLO" can be started locally with a front-panel switch, or remotely with a ground control signal. While the RM-100 is keying, an LED lights to indicate the circuit is busy.

This article shows how to construct the RM-100 CW Memory. Instructions are given for programming your own memory, or you can purchase one already programmed.* The RM-100 circuit can be

*JTM Associates, P.O. Box 843, Manchester, Missouri 63011 ($12.50); Babylon Electronics, Carmichael, California 95068 ($15.00).

built for under twenty-five dollars using the pre-programmed memory, or for under twenty if you program the memory yourself.

programming the memory

At the heart of any automatic message generator is a means to store binary information. In the past, code wheels with cogs, or diode matrices, have been popular as memories. A relatively new type of memory is now available to amateurs from surplus suppliers. The programmable-read-only memory integrated circuit, abbreviated as PROM, P.ROM, or fPROM, depending on the respective manufacturer, can be custom programmed in the field by applying the correct voltages to its inputs, following the manufacturer's instructions.

The Signetics 8223 Programmable ROM IC I chose for the RM-100 is the easiest to find.* The 8223 is supplied with all of its 256 memory cells at a TTL logic low or 0. The memory is programmed by fusing (burning out) microscopic wires in selected cells to generate a desired pattern of logic highs, or 1s. Once the memory has been programmed, the stored binary information can be recalled from each cell by applying an address word to the inputs of the device.

*JTM Associates, previously foot-noted, or Poly Paks, P.O. Box 942, Lynnfield, Massachusetts 01940 ($7.95).

The first step when programming is to decide what you want the memory to say. A Morse code *key-down* is defined as 1, while a *key-up* is 0. Using a pattern as shown in **fig. 2,** mark each of the eight rows of 32 memory cells where a Morse code *key-down* is desired. Remember that a dot will occupy one memory cell, a dash or letter space, three, and a word space, four. Ten consecutive *key-up* cells indicate an "end-of-message." **Table 1** lists the letters of the alphabet and numbers from 0 to 9 with the required number of memory cells for each character. The CW message can occupy 246 memory cells after the 10-bit allowance has been made for the end-of-message code.

Once you have established the program matrix, the following procedure should be used with the circuit shown in

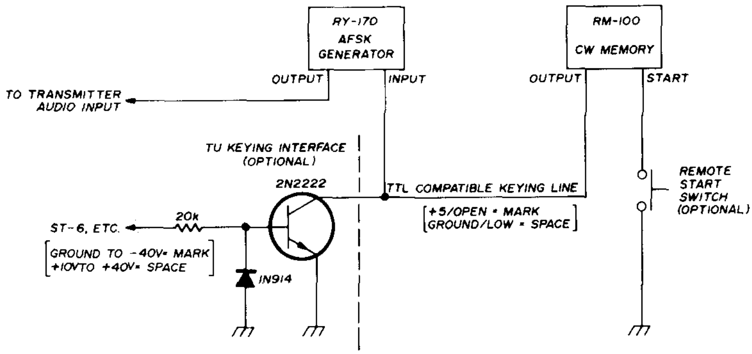


fig. 1. RATTline system interconnection showing RY-170 AFSK generator and RM-100 CW memory wired together with one possible interface circuit to a ST-6 RTTY terminal unit.

table 1. Memory cells required for letters, numbers and punctuation.

A 8	H 10	O 14	V 12
B 12	I 6	P 14	W 12
C 14	J 16	Q 16	X 14
D 10	K 12	R 10	Y 16
E 4	L 12	S 8	Z 14
F 12	M 10	T 6	
G 12	N 8	U 10	
1 20	6 14		, 22
2 18	7 16		? 18
3 16	8 18		. 20
4 14	9 20		/ 16
5 12	Ø 22	end of msg	10
		word space	4

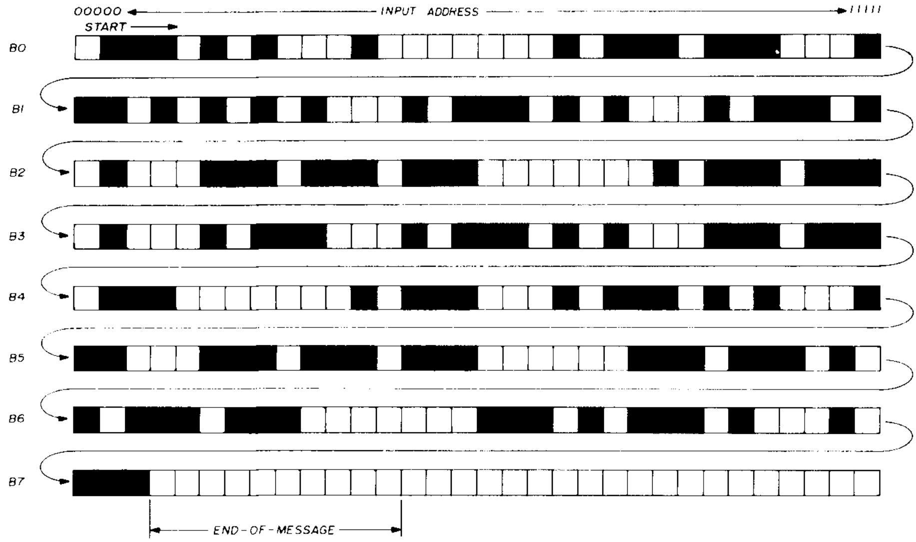


fig. 2. CW programming matrix consisting of eight rows of thirty-two memory cells, for a total of 256. Message shown here is "de W6LLO Palo Alto, Ca."

fig. 3 to program your memory.* Be careful – you only have one chance to correctly program each cell. Once the wire in a cell has been fused, it cannot be returned to its 0 logic state. If changes are required in the message, it is necessary to program a replacement integrated circuit.

programming procedure

The 8223 ROM IC is shipped with all outputs at logical 0. To write a logical 1 proceed as follows:

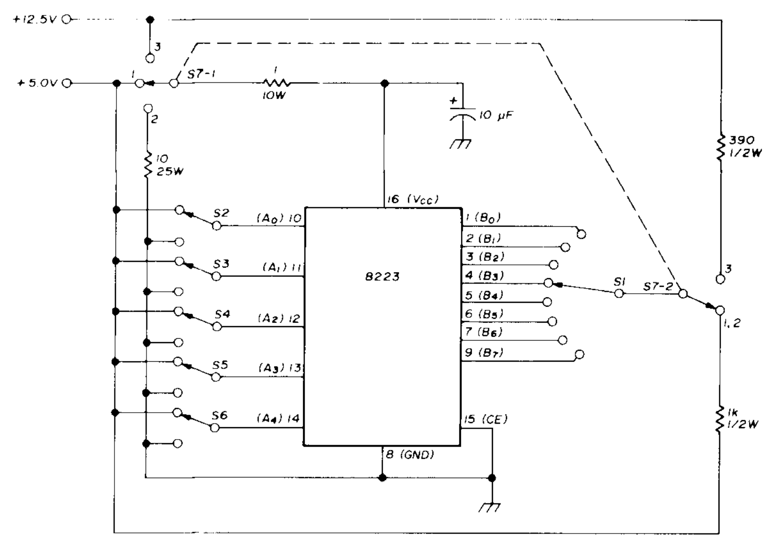
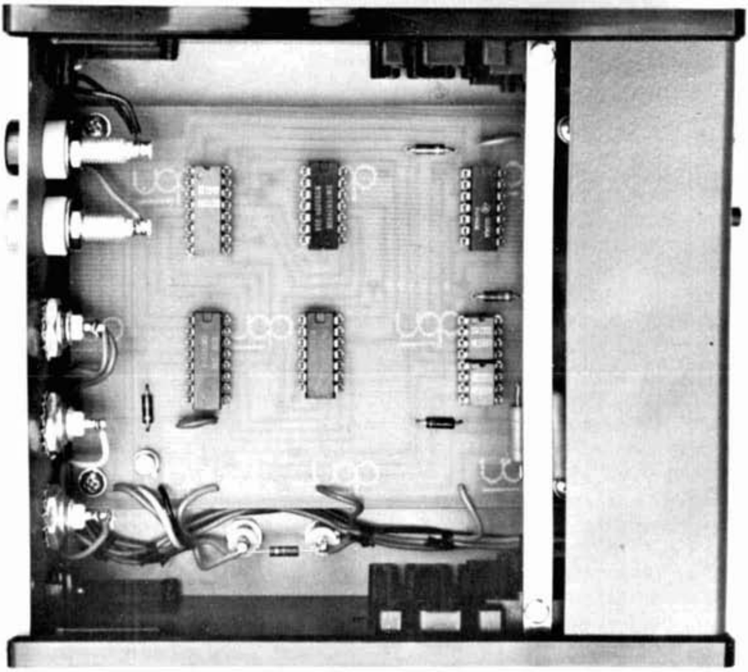


fig. 3. Programmer schematic for Signetics 8223 field-programmable read-only memory. The 10-µF capacitor from pin 16 to ground is required to eliminate noise from the supply line. During programming switch S7 must be in position 2 long enough for the 1-µF capacitor to discharge to less than 0.5 volt.

S1	single-pole, 9-position switch
S7	2P3T rotary switch with ground connected to the middle position of the first section. As V_{CC} (pin 16) is taken from 5 volts to 12.5 volts it will momentarily go to ground.



Inside of RM-100 as viewed from top. Resistor mounted on stand-offs is for LED indicator light.

1. Start with pin 8 grounded and V_{cc} removed from pin 16.

2. Remove any load from the outputs.

3. Ground the Chip Enable.

4. Address the desired location by applying ground (i.e., 0.4 V maximum) for a 0, and +5.0 V (i.e., +2.8 V minimum) for a 1 at the address input lines.

5. Apply +12.5 V ±0.5 V to the output to be programmed through a 390-ohm, 10% resistor. Program one output at a time.

6. Apply +12.5 V to V_{cc} (pin 16 for 50 milliseconds to 1 second (maximum) with a V_{cc} risetime of 50 microseconds or less. If 1.0 second is exceeded, the duty cycle should be limited to a maximum of 25%. The V_{cc} overshoot should be limited to 1.0 V maximum. If necessary, a clamping circuit should be used. The V_{cc} current requirement is 40 mA maximum at +12.5 V. Several fuses can be programmed in sequence until 1.0 second of high V_{cc} time is accumulated before imposing the duty cycle restriction.

*Programming instructions and **fig. 3** adapted from Signetics Catalog, 1972, page 4-10.

Note: Normal practice in text fixture

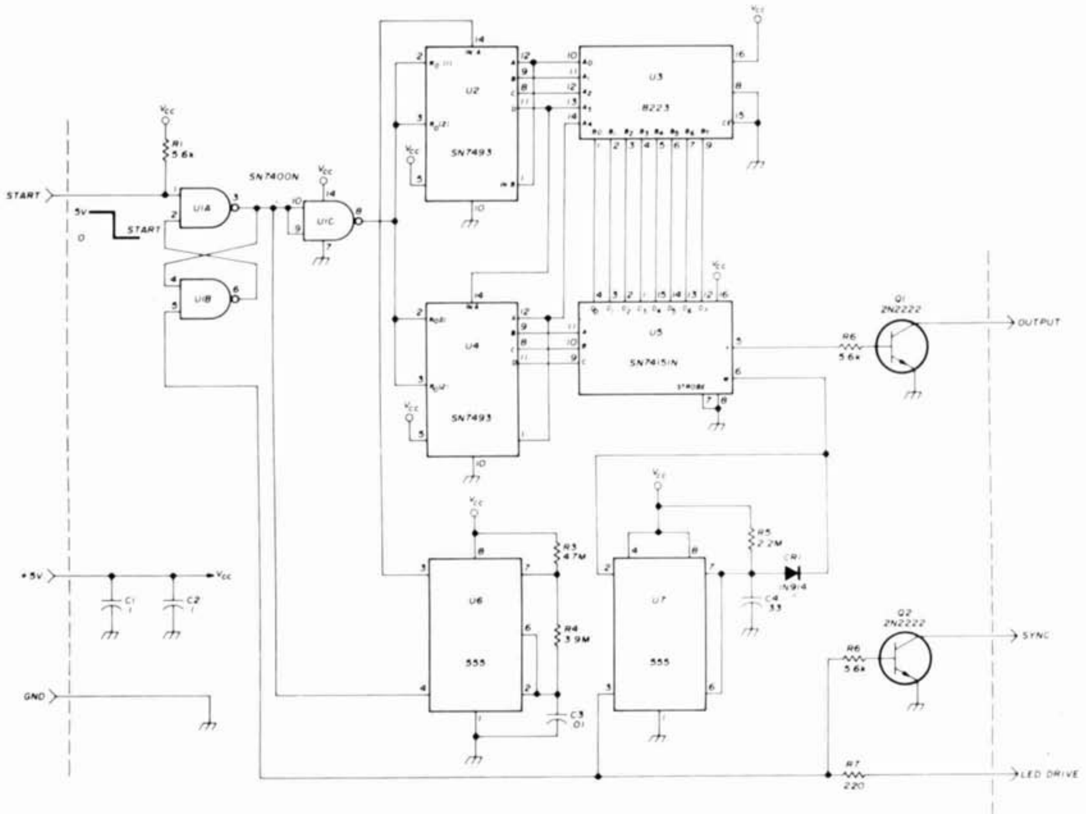


fig. 4. RM-100 CW memory schematic diagram.

layout should be followed. Lead lengths, particularly to the power supply, should be as short as possible. A capacitor of 10 μF minimum, connected from +12.5 V to ground, should be located close to the unit being programmed.

7. Remove the programming voltage from pin 16.

8. Open the output.

9. Proceed to the next output and repeat, or change address and repeat procedure.

10. Continue until the entire bit pattern is programmed into your custom 8223 ROM IC.

By now you have obtained a programmed memory, either by programming it yourself, or by purchasing it pre-programmed. Now you are ready to use it in the RM-100 circuit.

circuit description

The RM-100 CW memory consists of clock, divider, memory, data selector and end-of-message sense circuitry. The unit schematic is shown in **fig. 4**, and the component parts layout is given in **fig. 5**.

Rear panel of the RM-100.

Photographs of the completed RM-100 appear throughout this article.

The clock frequency established by timer U6, R3, R4 and C3 determines the dot length of the CW output. The code speed which results from a Morse dot length of 88 milliseconds was chosen, on suggestion from W6FFC, to keep the receiving RTTY machine in synchronism with the incoming pulses. Instead of printing garble, the machine will print blanks and Os in a combination which depends on the particular letter being sent.

Timer U7 detects when ten cells have passed without a keying event. Keying dots or dashes from the data selector discharges timing capacitor C4, whereas the timer is triggered on the trailing edge of each dot or dash. If a new keying bit does not discharge the capacitor within 880 milliseconds after the timer has been triggered, the timer output will reset the control flip-flop U1A and U1B, and the counters. The RM-100 CW message can be started again after the counters have been reset.

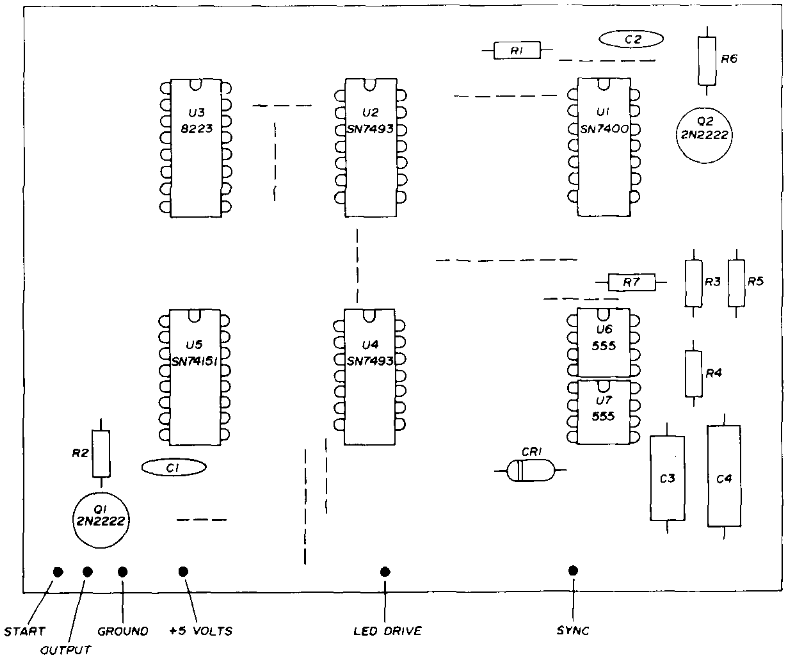


fig. 5. Suggested component layout for the RM-100. Dotted lines denote jumpers.

The clock output frequency is divided by binary counters U2 and U4. The first five outputs from the dividers supply counts 0 through 31 to address the memory, while the last three outputs are used to address the data selector, U5.

The memory, U3, is read out through the data selector, one cell at a time, in the order shown in **fig. 2**. The Q output from the selector drives the base of keying transistor, Q1, while the $\overline{Q}$ output is used by the end-of-message circuit.

The sync output from the memory is connected to an open-collector transistor switch which turns on for the duration of a message. The sync output will be used by upcoming RATTline accessories.

As with the RY-170, a separate supply is required to power the RM-100. A 5 ±0.25 Vdc regulated supply capable of 150 mA should be used.

construction

The RM-100 can be built using perforated or printed-circuit board. The cir-

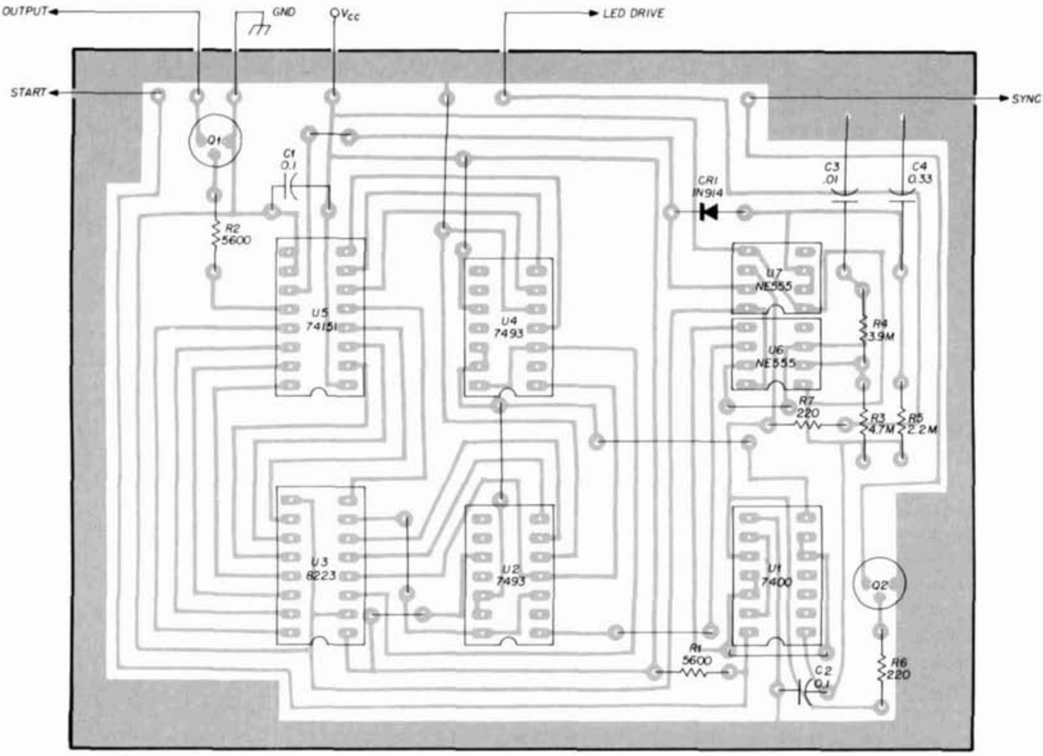
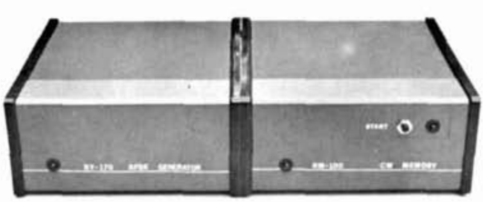


fig. 6. Full-size printed-circuit layout (foil side) for the 256-bit CW memory.

cuit should be placed in an enclosure, such as the Ten-Tec JG-5 shown in the photographs, to shield against rf.

An LED, powered from the 5-volt supply through a 220-ohm resistor, serves as a pilot light. A second LED is turned on by U7 when a message is being transmitted. A pushbutton switch on the front panel, which grounds the *start* control line, is used to trigger the memory.



RM-100 CW memory alongside the RY-170 AFSK generator.

The only critical components are the capacitors and diode used in the timers. High stability, low leakage capacitors should be used at C3 and C4 to maintain correct timing. A silicon diode is required at CR1 so that diode leakage will not effect timing in the end-of-message circuit.

Bypass capacitors should be used in at least two places on the circuit board. They should be near integrated circuits from V_{cc} to ground to filter transients. Molex pins hold the integrated circuits, and BNC jacks are used to connect signal inputs and outputs. Shielded cables are recommended when connecting the RM-100 with other parts of your system to reduce the possibility that strong rf fields will interfere with circuit operation.

Don't let rule 97.87 get to you! Now you can have automatic CW identification in your RTTY system with the RM-100 CW Memory.

ham radio

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HW-101 Transceiver

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five-band kilowatt linear

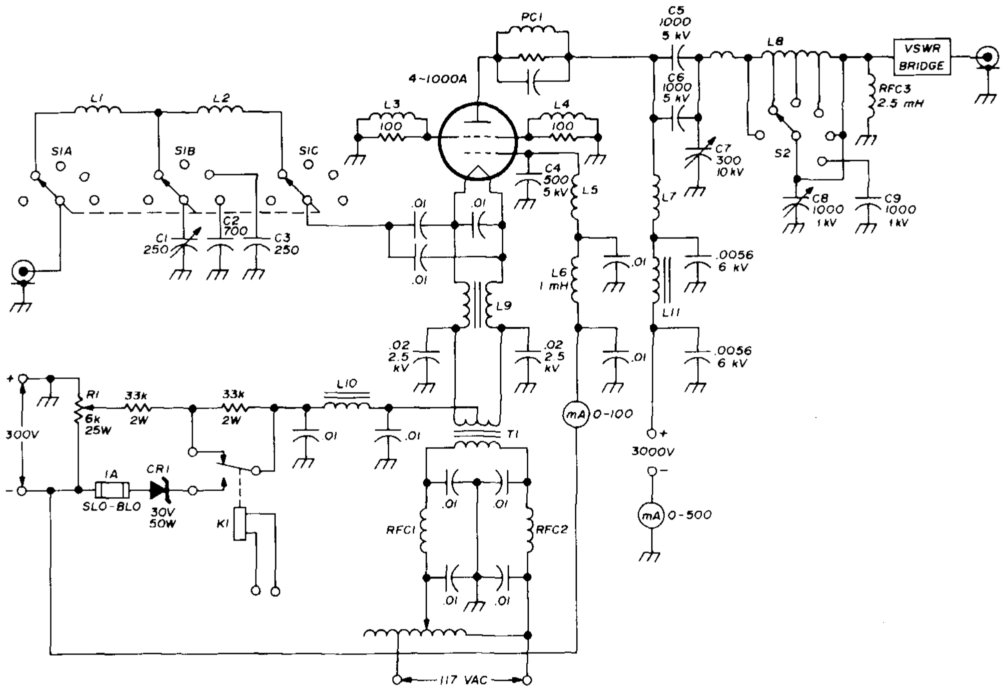
How to use beam power tetrodes efficiently and economically in the grounded-grid, grounded-screen configuration

John R. True, W4OQ, 10322 Georgetown Pike, Great Falls, Virginia 22066

With the proper design precautions, a power tetrode in a grounded-grid and grounded-screen configuration can provide more than 13-dB stable, parasitic free gain in the high-frequency spectrum An old 4-1000A which I use in this circuit (see **fig. 1**) operates at 2-kW PEP input when driven by an exciter rated at 100-watts output. Since power tetrodes have very high power gain characteristics, they require very little drive. Typically, the amplification factor of the grid is in the order of five to six times that of the screen. However, grid dissipation is very low and screen dissipation is considerably greater.

For amateur use, however, the high gain characteristic of the power tetrode is not always an advantage, because few amateurs use exciters that operate efficiently at less than 100-watts output. When the 100-watt exciter is used to drive a high-gain power amplifier, it must be loaded with a power attenuator, which wastes valuable power. One commercial linear recently offered on the market, for example, required a power-wasting 12-dB pad.

The high gain of the power tetrode can also lead to other problems, such as vhf parasitics which require extensive suppression. Also, a tetrode, grounded-filament, class-AB2 linear amplifier re-



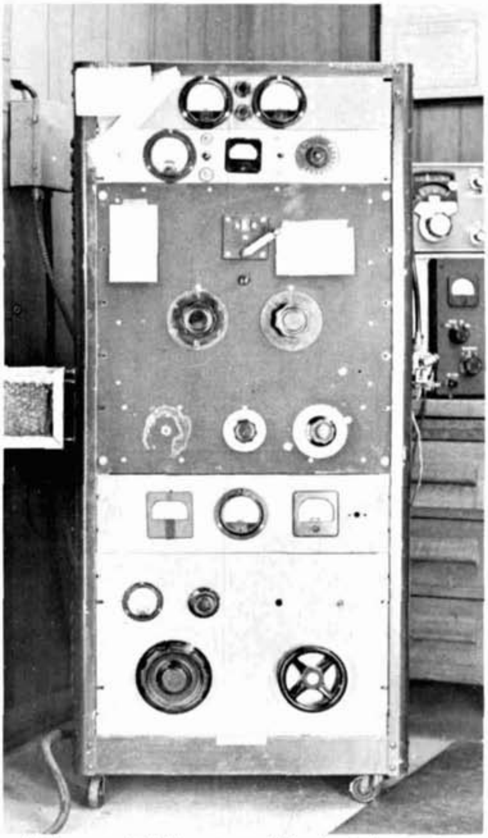
C1	25-250 pF air variable, 1000-volt working	L9	33 turns no. 10 enamelled bifilar wound on ½" ferrite rod, 7" long
C4	500 pF ceramic, 5 kV working (Centralab 858S)	L10,L11	2½" no. 18 wire wound around ½" ferrite rod
C5,C6,C9	1000 pF ceramic, 5 kV working (Centralab 858S)	K1	spdt relay, 117-Vac coil
C7	10-300 pF vacuum variable, 10 kV	PC1	20 pF ceramic capacitor (Centralab 852S) in parallel with four 470-ohm, 2-watt resistors and 4 turns no. 12 ½" diameter, resonated to 110 MHz
C8	1000 pF air variable, 1000 V		
L1,L2	see table 1	RFC1,RFC2	30 turns no. 16, closewound on ½" diameter wooden dowel
L3,L4	3 turns no. 12, 3/8" diameter, with 100-ohm, 2-watt resistor	S1	3-pole, 7-position ceramic switch
L5,L6	1 mH rf choke	S2	1-pole, 6 position switch (part of B&W 850A)
L7	plate rf choke, 1 amp (B&W model 800)		
L8	plate tank assembly (B&W 850A)	T1	filament transformer, 7.5 volts, 21 amps

fig. 1. Modified grounded-grid, grounded-screen, beam-tetrode power amplifier. Plate and screen power supplies are shown in fig. 3. Grid bias is provided by the zener diode, CR1.

quires a well regulated grid and screen supply. Using two tubes in parallel just multiplies the problems.

In recent years the grounded-grid triode has been used extensively as a linear amplifier for ssb and CW. Among its many advantages are excellent input/output circuit isolation (which means less parasitic problems), high power gains (10 to 13 dB), possibility of fixed-tuned bandpass input circuitry and no requirement for a regulated screen supply (or any screen supply at all, for that matter). Using the grounded-grid circuit, it is very easy to build a stable linear amplifier with low distortion products which is relatively free from harmonic distortion.

With all the advantages of grounded-grid triode power amplifiers, why even bother with a tetrode? Primarily because tetrodes are in abundant supply at ridiculously low prices – the broadcast industry practically gives them away after a certain number of operating hours. This is less expensive for them than experiencing a failure in the middle of an important broadcast. There are also a number of



Rack-mounted linear amplifier includes meters for vswr, grid and plate current, and filament, grid, screen and plate voltage. Variac-controlled power supply is located behind bottom panel.

power tetrodes available on the surplus market. However, if you are selecting a tetrode for a linear amplifier, choose one with adequate plate dissipation and filament emission to get the job done properly.

Experience has taught me that all is not gold that glitters. If the tetrode is used with the grid and screen grounded, the power gain will be low due to degenerative feedthrough power. Additionally, the grid hogs control of the space current while the screen loafs. To drive the plate to full output, excessively high grid current is required.

In an effort to cure some of these shortcomings, I built an amplifier with the grid less than fully grounded. It was bypassed with a 500-pF capacitor and the dc brought out for metering through an rf choke. This simple technique reduced the grid current (and increased screen current) to an appropriate value, but power gain was reduced because the screen is not as effective as the grid in controlling plate current. There had to be a better way!

the circuit

Considering the tremendous gain possible with a conventional grounded-filament, class-AB2 tetrode amplifier, I thought a hybrid compromise might be the answer. That is, to retain the isolation provided by the partially grounded grid and grounded screen, but to place some voltage on the screen to increase transconductance. That is easily managed with a grounded screen by biasing the filament negative in respect to ground. Thus, the screen becomes positive with respect to the filament. Unfortunately, so does the grid! Placing a zener diode in series with the filament return to the minus side of the screen supply will provide the grid with well-regulated bias for satisfactory idling as well as full input plate current.

However, this is not the complete answer. If you look carefully at the physical structure of the grid and screen of the 4-1000A, you will see that they form a sort of basket-woven cavity. When a positive voltage is placed on the screen, these cavities (with the filament) act as a triode oscillator above 100 MHz. By way of demonstration, if you ground the grid and screen of a 4-1000A and couple a grid-dipper to these leads, you will find that the screen is resonant at about 120 MHz. The grid is resonant at about 110 MHz, an ideal condition for *regeneration.*

Under these conditions, the screen is inductive in respect to the grid, the condition required for in-phase feedback.

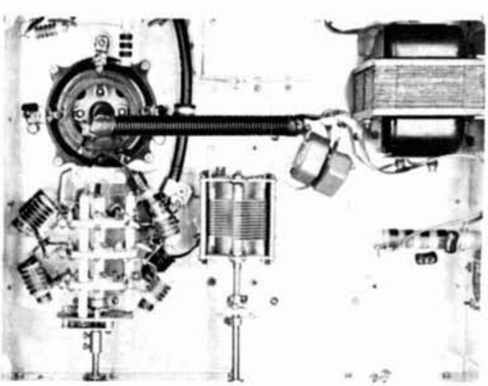
In fact, a 4-1000A self-oscillates near 110 MHz, and the 4-400A at about 140MHz. A pair of parallel power tetrodes may act like a push-pull oscillator, oscillating at a frequency that is dependent upon the length of their interconnecting leads.

If the grid is made to resonate higher (or the screen to resonate lower), self-neutralization occurs since the screen is capacitive in respect to the grid, producing *degeneration.* This is easily accomplished. As noted before, the small 500-pF bypass capacitor slightly raises the resonant frequency of the grid. A small inductor in series with the screen shifts its natural resonance point below that of the grid, resulting in neutralization.

power supply considerations

If you trace the plate-current path in **fig. 1,** you will find that the plate current flows through both the plate and screen supplies. Therefore, the screen supply must furnish both screen and plate current. The screen voltage must also be added to the plate voltage when calculating plate input power (subtract the zener voltage drop). It should be obvious, therefore, that the screen supply must provide very good voltage regulation.

Using the 4-1000A as an example, assuming a plate supply of 3000 volts, a screen supply of 300 volts and zener bias of 30 volts, the idling plate current will be about 125 mA. With 100-watts of excitation and a desired plate power input of 1 kilowatt, grid current is approximately 30 mA, screen current is about 100 mA, and plate current is approximately 300 mA.



Underneath the linear amplifier chassis. Input matching network is at lower left.

To reduce noise generation while receiving, some means must be provided for completely turning off the power tube

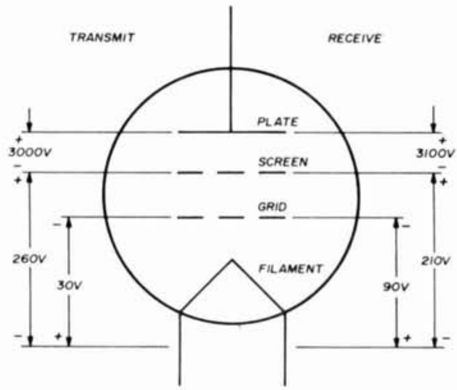


fig. 2. Operating voltages for the 4-1000A power amplifier during transmit and receive. Cutoff voltage on receive is provided through the contacts of relay K1 (see text).

when not transmitting. **Fig. 1** shows the circuit I use to accomplish this. When transmitting (relay K1 picked up), the grid is minus with respect to the filament by the voltage drop of the zener diode. When the relay drops out (receive position), the filament assumes the positive voltage offset from a tap on the screen supply bleeder resistor. A grid-filament bias of −90 volts is more than enough to completely cut off a 4-1000A with the plate and screen voltages indicated in **fig. 2.**

A complete schematic of the plate and screen power supplies is shown in **fig. 3.** All supply voltages are brought up to full operating levels with a variable transformer (Powerstat). The large filter capacitors require a lot of current to load them to full voltage, and this procedure reduces the surge current through the silicon diodes. Another Powerstat is used with the filament transformer to reduce the thermal shock of an instant-on filament switch.

The plate and screen power supplies

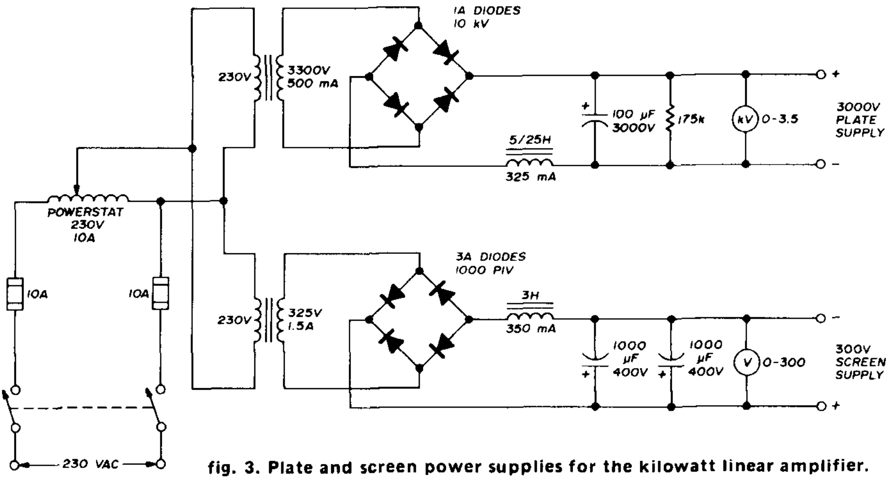


fig. 3. Plate and screen power supplies for the kilowatt linear amplifier.

use common protective fuses. This avoids the possibility of losing the plate supply with the screen supply still on, which would surely destroy the screen of the 4-1000A. The 1-amp slo-blo fuse between the grid-bias zener diode and the minus side of the screen supply protects against overloads, including parasitics. Any excessive dc cathode current will blow the fuse, automatically returning the grid-filament bias to the cutoff value.

input network

Since normal voice waveforms have an approximately 3.5:1 peak-to-average ratio, this must be considered when computing the input impedance to the grounded-grid stage. At 1-kW input total required filament emission is 430 mA (300 mA plate current + 100 mA screen current + 30 mA grid current). With a 3.5:1 peak-to-average voice ratio, peak filament emission is 1.5 amperes (3.5 x 430 mA). Therefore, filament input impedance is

$$Z_i = \frac{P_i}{I^2} = \frac{100}{(1.5)^2} = \frac{100}{2.25} \cong 45 \text{ ohms}$$

where Z_i is the input impedance, P_i is the input (drive) power (100 watts), and I is the peak filament current.

The graphical design of a T-network for matching 50-ohm coaxial cable to the 45-ohm input impedance of the 4-1000A is shown in **fig. 4.**[1] In this graphical solution, the transfer impedance (Z_T) was chosen to be 150 ohms. As can be seen, X_C = 51 ohms, X_{L1} = 71 ohms and X_{L2} = 69 ohms. The Q of this network is approximately 3. Practical network component values for each of the high-frequency amateur bands are listed in **table 1.**

The T-network inductors L1 and L2 are wound on ½-inch polyethylene tub-

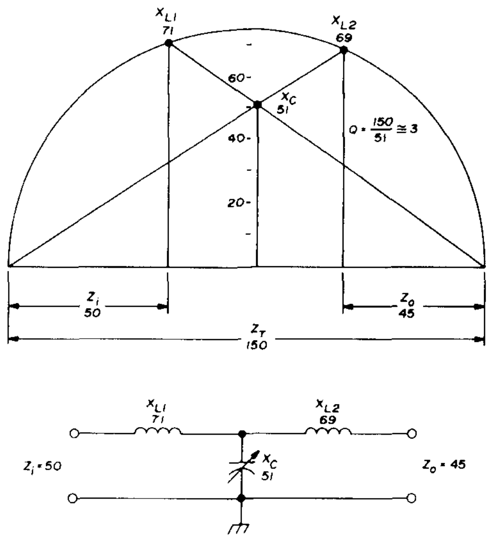


fig. 4. Graphical design of the T-network used at the input of the power amplifier.

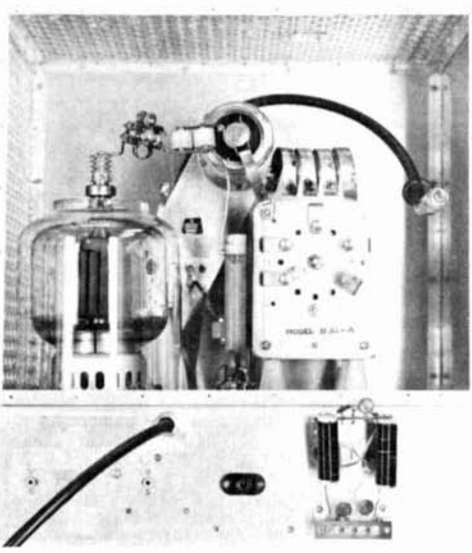
ing. Number-14 Formvar is used for the 80- and 40-meter coils while number-12 Formvar is used for 10, 15 and 20 meters. A ½-inch wooden dowel is inserted in to the tubing during winding to keep the tubing from being deformed.

After the coils are wound, a short length of ½-inch OD ferrite rod (about 1-inch long) is inserted into the tubing and adjusted for the proper inductance value given in **table 1**. By using 5% fixed mica capacitors across the inductors and a grid dipper to check for resonance, it is possible to adjust them very close to their required inductance values. When the inductors are completed, coil dope is used to hold the turns and the ferrite slug in place.

output network

The output pi network is based on the B&W model 850A bandswitching pi-network inductor which includes a built-in bandswitch. As shown in **fig. 1**, an additional switch contact was added to permit the use of a 1000-pF fixed capacitor in parallel with C8 on 75 meters.

The rear plate of the antenna loading capacitor (C8) is used as the common ground point for the output circuit. (The rear plate of the input capacitor, C1, is used as the common ground point for the input circuit). Both the input and output coaxial cable connections are made at their respective common ground point and switch. These cables are connected directly to the exciter and the vswr bridge without any terminations at the chassis. This reduces input-output coupling.



Rear view of output components of the linear showing the 4-1000A and B&W pi-network inductor.

table 1. Component values for input T-network described in fig. 3 (X_C = 51 ohms, X_{L1} = 71 ohms, X_{L2} = 69 ohms).

frequency	L1	L2	C
3.60 MHz	3.14 μH	3.05 μH	865 pF
3.90 MHz	2.90 μH	2.81 μH	800 pF
7.15 MHz	1.58 μH	1.54 μH	436 pF
14.20 MHz	0.80 μH	0.77 μH	220 pF
21.25 MHz	0.53 μH	0.52 μH	147 pF
28.80 MHz	0.39 μH	0.38 μH	108 pF

summary

As indicated by the brownish lace pattern at the base of the tube envelope, the "well-used" 4-1000A broadcast tube I am using must have had a zillion hours on it when I first got it. It has been in use for over three years at my station and is still going strong. If it goes out tomorrow, I will have had more than my money's worth from it and the spare I purchased for $5 each.

Despite the work of building (and rebuilding) and debugging the modified 4-1000A grounded-grid linear it has been well worth the effort. My SB-401 exciter can drive the final to well over 2000 -watts PEP without strain, and can loaf along at half power and still drive the final to a full 1-kW input. When connected to my five-band antenna system on one tower[2] the results are quite gratifying.

references

1. I.L. McNally, "Graphical Solution of Impedance-Matching Problems," *ham radio*, December, 1969, page 26.

2. John R. True, W4OQ, "Grounded Vertical Tower Antenna System," *ham radio,* April, 1973, page 16; May, 1973, page 56.

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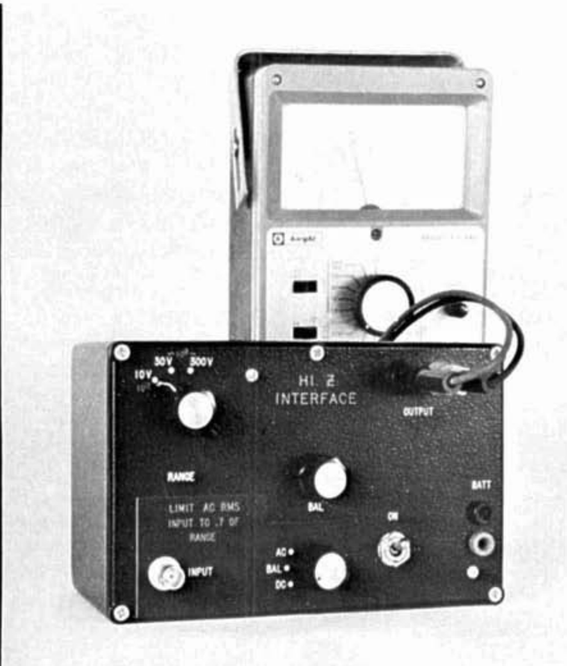


high-impedance meter interface

A high accuracy meter-interface unit for ac and dc measurements that features up to 1-million megohms input resistance

J.R. Laughlin, 11918 Pompano Lane, Houston, Texas

Making accurate measurements with a voltmeter is often difficult because of the input resistance of the meter itself. Errors due to the loading effect of the voltmeter are often nearly impossible to evaluate, particularly in transistor circuits where the dynamic characteristics of the circuit are difficult to accurately analyze. More importantly, many of these erroneous readings might go unnoticed as you hurry to check out a circuit. An accumulation of errors here and there often add up to a puzzling situation when troubleshooting a defective or inoperative circuit.

The standard vom with 20k V input resistance can be a disaster in many circuits, either requiring tedious calculations to correct for its loading, giving misleading results to those not completely familiar with the meter and circuitry or simply being useless as a measuring tool. Even the heralded vtvm, with its 10-megohm input resistance, will cause significant errors in many circuits.

Having long been troubled by voltmeter errors due to loading, I have made an effort to overcome and eliminate, as well as practically possible, this source of trouble. First, I decided that some type of interfacing unit should be designed to be used with existing equipment. Since my workshop contains a varied assortment of different types of meters, from the very cheapest to more expensive laboratory types, it would represent a needless waste of revenue to obsolete these. Also, the design of the interfacing unit would be greatly simplified by making use of the basic structure of these existing meters.

Portability, a must, dictates battery operation. To extend battery life and reduce operating costs, micropower operation is mandatory. The final instrument incorporates the basic specifications given in **table 1**.

circuit

To achieve extremely high input resistance a special dual fet with exceptionally low gate-leakage current was chosen to form the heart of this instrument (see **fig. 2**). For maximum linearity and accuracy the fet is combined with a high quality operational amplifier. The two are connected as a voltage follower with a gain of one. One important parameter of the op-amp is its very low power consumption. This results in truly low battery drain for the instrument as a whole, greatly prolonging battery life, reducing operating expense and eliminating the annoyance of frequent battery replacement.

The amplifier will handle an input voltage, without overload, of somewhat over 10 volts. When used within this range the input gate of the fet is connected directly to the circuit being measured. This mode of operation offers the highest input resistance obtainable from the amplifier. The only loading on the circuit being measured is the leakage current of the fet gate, this current being in the order of 0.2 picoamperes (0.0000002 microamps). Contrast this with the 50 microamps that a standard vom will draw, or the 0.1 microamps drawn by a vtvm when measuring one volt full scale.

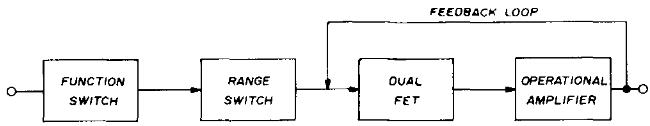
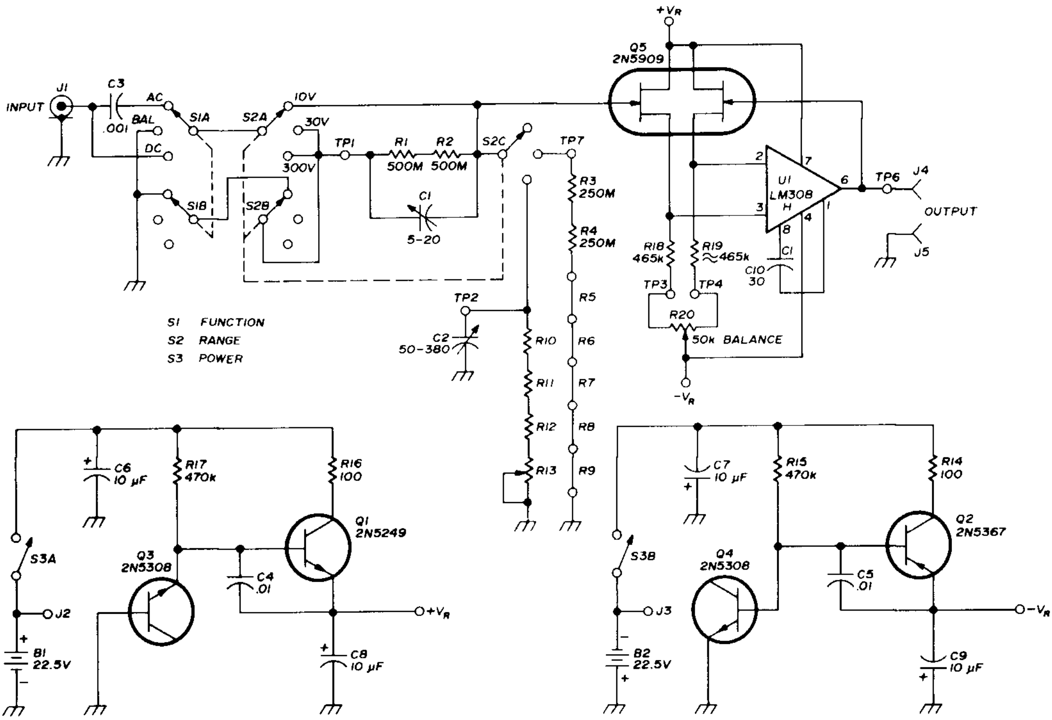


fig. 1. Block diagram of the high-impedance meter-interface unit. Instrument will solve dc measurement difficulties caused by circuit loading.

For measuring voltages in excess of ten volts a resistive voltage divider is necessary to keep the voltage level applied to the fet gate within its normal operating range. This voltage divider necessarily reduces the input resistance of the amplifier. To minimize loading on the higher ranges a voltage divider with approximately 1000 megohms total resistance was chosen. Unfortunately, this is considerably lower than the intrinsic input resistance of the fet, as enjoyed on the

table 1. Basic specifications of the high-impedance meter interface unit.

Dc input resistance, 0-10 volts	greater than 1-million megohms
Dc input resistance, 10 volts up	1000 megohms or greater
Supply voltage (battery)	± 22.5 volts dc
Current drain	500 μA
Battery type	Eveready type 412
Battery life	295 hours, continuous usage
Accuracy, 0-10 volts	0.1% or better
Accuracy, higher ranges	depends on accuracy of dividers



C1	5-20 pF ceramic trimmer (Erie type 503). (Do not use a compression-type trimmer here.)
C2	50-380 pF compression trimmer (Elmenco type 465)
J1	BNC connector (Amphenol UG-657/U)
R1,R2	to total 1000 megohms, 1% (matched pair)
R3,R4	to total 500 megohms, 1% (matched pair)
R5-R9	values as required for balance (see text)
R10,R11,R12	to total 33 megohms, 5%
R13	2-3 megohm trimmer (Mallory 26L1 or 26L4)
R14,R16	100 ohm, 10% carbon
R15,R17	470k, 10% carbon
R18	465k, film-type preferable
R19	465k, approximately (see text)
R20	50k, 10-turn potentiometer
R21	220k, 10% carbon
S1	2-pole, 3-position ceramic wafer rotary switch
S2	3-pole, 3-position ceramic wafer rotary switch
S3	dpdt toggle switch

fig. 2. Schematic diagram of the high-impedance meter-interface unit. Three dc ranges are provided: 10, 30 and 300 volts; ac rms inputs are limited to 70% of dc range.

zero to 10-volt range, but it is still 100 times greater than the standard vtvm input resistance.

Although a higher value of resistance can be used in the divider network, this will cause degraded performance at higher operating temperatures. This brings up a point about fet gate leakage vs temperature – the gate leakage increases approximately 10 times for each 18°F increase in temperature. Hence, this instrument should be kept cool (room temperature) for maximum input resistance on the zero to 10-volt range.

Two voltage regulators are used in the battery supply circuit. These were not put there because of a great need for supply regulation, although the regulation will certainly tighten drift specs some, but the primary purpose of the regulators is to allow use of battery voltage in excess of the voltage rating of the op-amp. The absolute maximum supply voltage rating of the LM308H op-amp is ±18 volts.

The closest available battery voltage that does not exceed this rating is a 15-volt unit. Use of a 15-volt supply would have placed the operating voltage of the amplifier uncomfortably close to the desired 10-volt input signal handling level. Of course, this 15-volt supply would have been the *starting* voltage of the battery and as the battery began to "droop" with usage the already uncomfortable margin would quickly become more narrow. A marginal situation like this would contribute to shortened battery service and danger of overload with normal input signal levels.

The input network consists of a resistive voltage divider with frequency compensating capacitors for better ac performance (frequency response), switching arrangement and blocking capacitor for ac amplification only, if desired. On the zero to 10-volt ac range the two 500-megohm resistors are switched from fet gate to ground. This provides the necessary dc path to ground for the fet gate, which otherwise would not exist due to the presence of the dc blocking capacitor, C3.

Resistors of the extremely high values used in this divider are not common stock items. Their procurement can be a real problem through standard channels. All of the resistors used here were supplied by the Resistance Products Company.* This organization specializes in very high resistance products and can supply them in almost any tolerance desired. The parts list describes the type and part number of the resistors I used.

The actual total resistance of the resistive divider is not as important as the fact that it must be high and that the ratio between R1 + R2 and the two ground legs must be close to that required for the proper division ratio. As used in this particular instrument, the voltage division ratios are 3:1 for the zero to 30-volt range and 30:1 for the zero to 300-volt range. This places the ratio between R1 + R2 and the two ground legs at 2:1 and 29:1. For a 1000-megohm value for R1 + R2 the zero to 30-volt ground leg is exactly 500 megohms. For the zero to 300-volt range the ground leg is 34.48 megohms.

*Resistance Products Company, 914 South 13th Street, Harrisburg, Pennsylvania 17104.

The high-impedance meter interface instrument is built into a cast aluminum box, Bud type CU347.

The following is a general formula for figuring the resistance ratios for any voltage ratio:

$$\text{Resistance ratio} = E_{in}/E_{out} - 1$$

$$\text{Ground leg resistance} = \frac{R1 + R2}{\frac{E_{in}}{E_{out}} - 1}$$

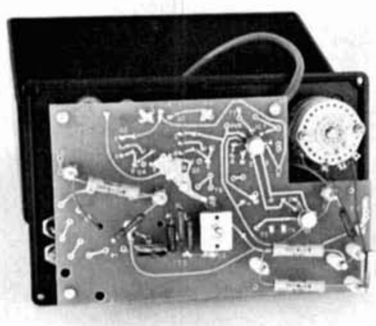
These simple expressions will allow easy computation of resistors required for any situation.

The instrument described here was designed to be used primarily with a readout meter having scales ending in 10 and 30. Hence, the ranges of 10, 30 and 300. For meter scales different than the above, the ranges of the interface will undoubtedly need to be scaled to match.

construction

The instrument is housed in a Bud Radio type CU347 cast-aluminum box. A good paint job with engraved legends will result in a professional appearance. The front panel must be drilled to accomodate the input jack, function switch, balance pot, range switch, power-on toggle switch, battery check jacks and output terminals. Care should be exercised here to insure that the switches are not mounted too close to the edge so as to obstruct the case sides.

The circuit board is mounted on standoffs 1.5-inch long. This provides adequate clearance between the board and panel-mounted items. Location holes for the standoff legs fall in the center of the



Most of the major components of the high-impedance interface unit are built on a printed-circuit board (see fig. 3). Switches, balance control and jacks are mounted on front panel.

small round mold marks on the inside surface of the front panel. Also, the circuit board can be used to dimension these holes. High quality Teflon standoff terminals were pressed into the circuit board to hold R1, R2 and R3. Input wiring was run point-to-point instead of bundling to reduce interwiring capacitance and leakage currents. Teflon wire was used throughout. Be certain to use only ceramic switch wafers on the range and function switches. The input jack should have a Teflon insulator.

Extra positions on the circuit board accommodate a number of resistors that may be connected in series to trim the exact value of the ground leg resistors in the voltage dividers. If quality resistors are purchased all of these positions will probably not be used.

Note. The circuit board contains pads for compensation components that are used on other types of micro power op-amps other than the LM308H shown in the parts list.

Here are some tips on placement of parts. The input gate is not connected to a board mounted pad but to a Teflon standoff. Room was provided on the board to accommodate very long resistors for R1 and R2. Some of these may be found surplus or purchased as replacements for elements in high-voltage probes. If short resistors are used as suggested in the parts list the standoffs will have to be positioned closer to the fet.

After mounting R1 and R2, C2 may be soldered directly to the standoffs holding these resistors as shown on the parts location diagram. When mounting the fet, Q5, be certain to form the leads so that they enter the proper pads on the board without shorting to each other. If the 2N5909 is used as suggested, the legs will not fall directly into the proper pads.

After completion of all wiring, the circuit board and all standoffs and switch wafers should be thoroughly cleaned with alcohol (pure) to remove all trace of rosin, fingerprints or other contaminants. The high megohm resistors should be cleaned also as their value can be significantly altered by contaminants on their surface.

checkout

First, measure battery drain imposed on each battery. This current should be approximately 0.5 mA. Significantly higher currents indicate trouble and should be investigated before proceeding.

The output voltage of the regulators should be measured. This voltage level will vary but will usually fall between 15 and 18 volts. If higher than 18 volts, the cause should be found and steps taken to being it to normal.

With the function switch in the *BAL* position, check to see if the balance control will vary the output + and − by approximately the same amount. Normal variation is around ±50 millivolts.

On the 10-volt range, dc input voltages both, + and −, should be reproduced exactly at the output up to the overload point. Overload will normally occur at about 1 or 2 volts below the supply voltage. Millivolt differences between input and output can be adjusted to zero with the balance control.

The two higher ranges should be checked, and trimmed if necessary, for accurate voltage division ratios. This procedure calls for an accurate and linear readout standard.

Input resistance levels as encountered here are difficult to measure with standard equipment. A simple check to demonstrate the high input resistance is to connect a standard 10-megohm vtvm in series with a 10-megohm resistor and apply a voltage to the series combination. Note the voltage reading on the vtvm; it should be approximately half the supply voltage. Now, alternately connect and disconnect the high-impedance interface to the probe of the vtvm while noting the change in reading of the vtvm. The 1000-megohm input resistance of the two higher ranges should cause only about a 1% change in the reading of the vtvm. The input resistance of the 10-volt range should cause no noticeable variation in the vtvm reading.

An audio oscillator is needed for checking the ac characteristics of the interface. Stray capacitance plays an important role in the frequency response of the instrument. Consequently, the trimmer capacitors C1 and C2 must be adjusted a little at a time and the instrument put into its cabinet after each adjustment to note the effect. There is no adjustment necessary for the 10-volt range.

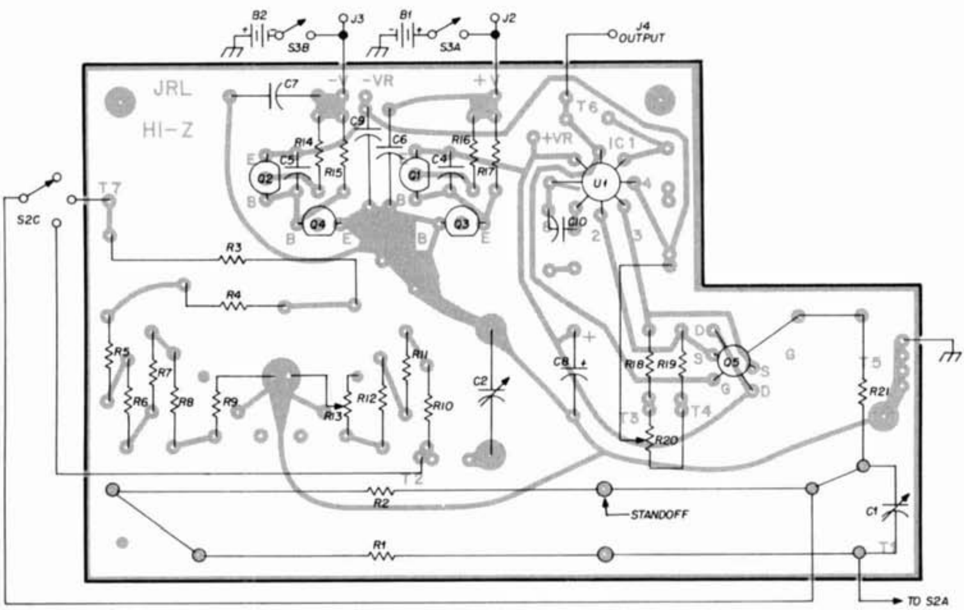


fig. 3. Printed-circuit layout for the high-impedance meter-interface unit.

The simplest method of adjustment can be accomplished by feeding a 100-Hz square wave into the instrument and adjusting C1 on the second range for best response with the instrument in the cabinet. Next, C2 is adjusted with the range switch on the highest range for best square wave response, with the instrument in the cabinet. Be certain that your oscilloscope has sufficient response to exactly reproduce the square wave as it comes out of the generator.

If only a sine wave oscillator or a 60-Hz source is available, the adjustments can be made so that exact reproduction of the input amplitude occurs at the output terminals with the instrument in the cabinet.

ham radio

IC logic families

A rundown on popular logic circuits, their interfaces, and compatibility

Hank Olson, W6GXN, Stanford Research Institute, Menlo Park, California 94025

The use of the Fairchild μL914, and other members of the resistor-transistor logic (RTL) family, is well documented in the amateur radio periodicals. The Fairchild μL900, μL914, and μL923 (all from the RTL family) were the first digital integrated circuits to be offered in low-cost epoxy packages. An early article by Lancaster[1] pointed the way for many other experimenters, and for years RTL was the most-used logic family among hams. A number of other firms rushed into production of RTL to "second-source" these popular ICs; all but several of them dropped out of the competition in a year or two. Motorola went Fairchild one better – offering an expanded RTL family in plastic dual-inline packages (DIP). Some of these plastic DIPs are also offered as part of the Motorola HEP line, which are more easily obtained than most other ICs. The HEP line also has RTL ICs in the TO5 metal can package.

The following selection guide should be helpful when planning your next project using ICs. A brief description is given of seven popular logic families together with information on interchangeability and compatibility. Additional data on device details and applications is available from the manufacturers mentioned.

RTL logic

Although RTL is widely used in ham circles, and also fairly inexpensive, it has some limitations. RTL is a relatively slow form of logic. While some members of the family are rated up to 8 MHz, the family is not usually used above 1 or 2 MHz – especially the low-power versions. RTL requires a supply voltage of 3.6 Vdc at relatively high current. A modest logic array of RTL devices can often require several amperes. RTL has poor noise immunity, the level of ripple or transients on the power supply bus above which false triggering can occur. This low ripple limitation, together with the large current requirement, can make the power supply quite expensive.

The nice features of RTL, other than economy, are the ease of understanding and durability in the hands of the beginning electronic logician. As such, it is no wonder so many technical people cut their teeth on RTL. **Fig. 1** shows an RTL two-input gate; it is similar to one-half of a μL914 or HEP584. This circuit could also be built of discrete components — say a pair of 2N708s, a 470-ohm resistor, and two 620-ohm resistors (to use standard components).

Operation. If both inputs are grounded (or open circuited), no current will flow in either transistor, and the output voltage level will be at +3.6 V. Now, let input 1 be raised to +2.2 V. This will forward-bias Q1, the 450-ohm load resistor will conduct current, and the output voltage will drop. Assuming the base-to-emitter drop to be 0.6 V, that puts 1.6 V across the input resistor: base current = 1.6V/640 ohms = 2.5 mA. This amount of base current is more than enough to saturate Q1, and output will drop to nearly ground level, say to +0.5 V. If we now make input 2 rise to +2.2 V, little change in the output will occur. So, if input 1 *or* input 2 is high, the output will be low.

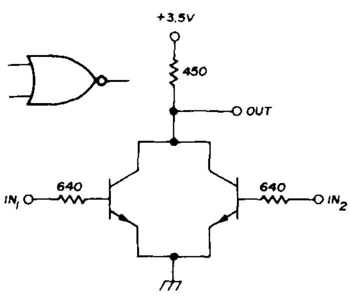


fig. 1. RTL 2-input NOR gate.

We will now define high as 1 (or true) and low as 0 (or false). Then, looking at our RTL gate we can say that if input 1 *or* 2 is 1, the output is 0. Since the output gives a false output to either of two true inputs we must call this gate a NOR gate (short for NOT-OR). Similarly, an inverter, as shown in **fig. 2**, is sometimes called a NOT gate. Such a NOT gate is contained in a Motorola MC789P, hex inverter (there are six in one package).

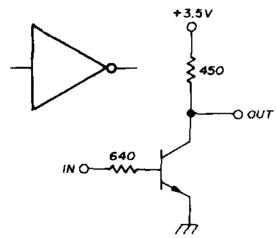


fig. 2. RTL inverter (NOT) gate.

By combining a NOR and NOT circuit we have an OR, as shown in **fig. 3A**. The output is 1 (true) if either input 1 *or* 2 is 1 (true). Similarly, by using a NOT gate ahead of each of the two inputs to the NOR gate, we can form an AND. This is shown in **fig. 3B.** The output is 1 (true) if both input 1 *and* input 2 are 1 (true).

A NOT gate can be made using a two-input NOR gate by simply grounding one of the two inputs. Therefore, all of the circuits thus far described can be constructed using one or more sections of μL914 gates. If one wanted just one NOT, NOR, or OR function, the μL914 would be the least expensive way of implementing it. Similarly, if just one AND function is desired, an MC724P is the cheapest way to build it. However, in larger systems (where a number of IC packages are used) gates are not usually used as inverters, since a hex inverter costs about the same as a quad two-input gate.

Although they are not usually drawn that way in logic diagrams, any of the several flip-flops can be made up of gates.

Fig. 4 shows how a number of flip-flops are made up, along with their usual logic circuit symbols.

Load factor. One of the nice features of IC logic is the simple system of fan-in and fan-out numbers that most manufacturers provide. In RTL, the Fairchild and Motorola fan-in and fan-out numbers are compatible. A fan-in of 1 is the loading that a low-power gate (μL910, say) puts on whatever is driving it. The fan-out is the number of such gates (as loads) an IC is capable of driving. For instance, the fan-out of a μL910 is 4; it can drive one input of another μL910 plus one input of a μL914 (fan-in of 3).

These load factors apply only within the RTL family, however, and more care must be exercised when trying to interface RTL with other logic families. This is not just an academic problem – say getting from an RTL system into a TTL system – because field requirements often place unlike pieces of apparatus together. Fortunately, there are a number of family-interface ICs available, and otherwise the transition circuitry can be built using discrete components.

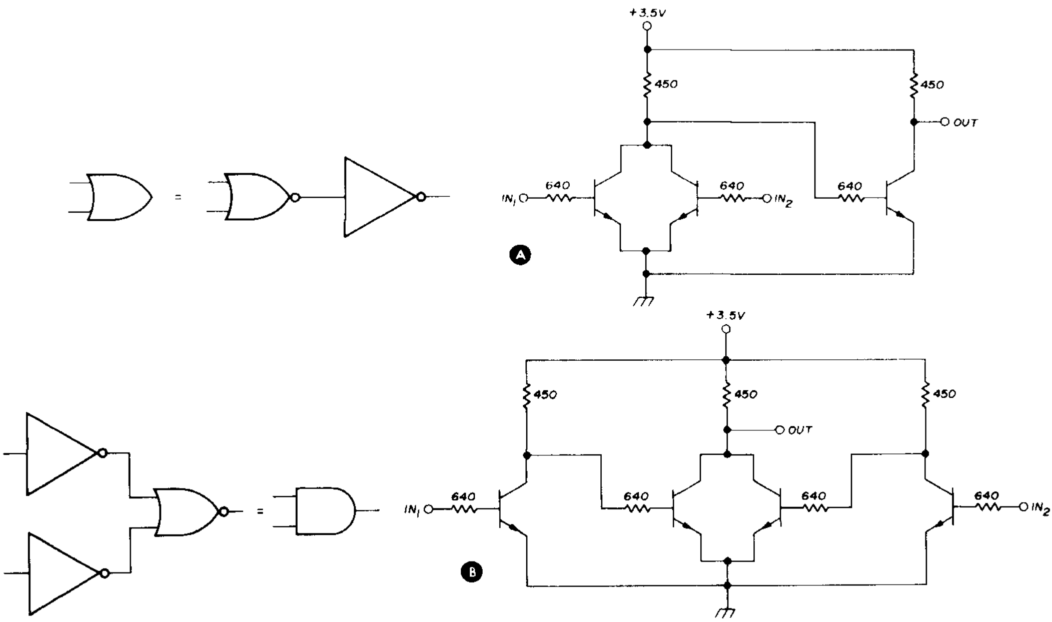


fig. 3. RTL OR gate (A) and AND gate (B).

DTL logic

Historically, diode-transistor logic (DTL) comes right behind RTL as an IC. However, DTL was extensively used as a logic form in discrete circuitry before ICs were developed. It is common to find old logic systems full of cards of 2N404s and 1N658s still in use in pieces of discrete DTL systems. Of course, all of the components on one whole card of such a system could be replaced today by one IC – less expensively! Such a discrete DTL gate is shown in **fig. 5**.

μL930 family. Usually, when one speaks of DTL, the μL930 family is meant. There are a number of other DTL families around, but they are the "losers" in the industry-wide acceptance game. Like the μL900 (RTL) series, Fairchild also originated the μL930 (DTL) family.

In the μL930 series, there are no round can packages available in plastic, although they are fairly common in round metal can packages. The round metal can package is often referred to as TO5 because the can size is the same as that of a TO5 (three lead) transistor. While most round metal can ICs have 8, 10, or 12 leads and so cannot strictly be called TO5, the TO5 can description has been widely given to them. DTL is also available in the dual inline package (DIP) both in plastic and ceramic, and in the ceramic flat-pack.

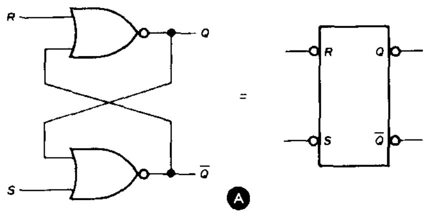
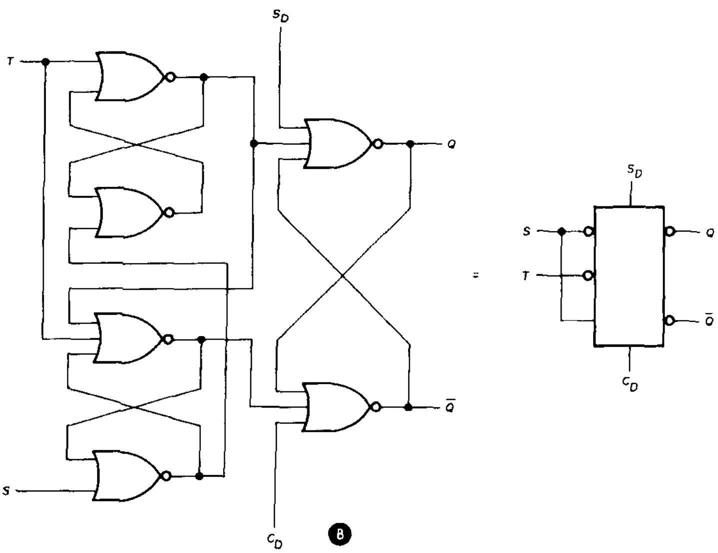


fig. 4. Flip-flop circuits. A set-reset (RS) type is shown in (A); a type D is shown in (B).



Amateur DTL users will probably be most interested in the plastic DIP form of DTL, but often the other styles are offered as surplus at low prices. In an earlier article, I showed how to use surplus flat-pack μL930s and μL946s in an amateur wind-direction indicator.[2] Of course, the flat-pack style IC is not limited to DTL; nearly all logic families use it for their MIL-spec package.

Current-sinking logic. Fig. 6 shows a DTL gate (¼ of μL946 or MC846P). Note that both inputs are via diodes, which might at first look as though they are connected backward. Fear not, the diodes are shown correctly, because we must draw current out of the input when using this sort of logic. For this reason DTL is called current-sinking logic. (We will see that some other forms of logic are also current sinking as we go on.)

Unlike RTL, if a DTL gate has its inputs left open, the transistors in it are conducting, and the output is low or zero. Also, for positive logic, a simple DTL gate is called a NAND gate. When input 1 *and* input 2 are high (or open) the output is low. By following the gate of **fig. 6** with an inverter (such as 1/6 of an MC836P) we create an AND gate, as shown in **fig. 7**.

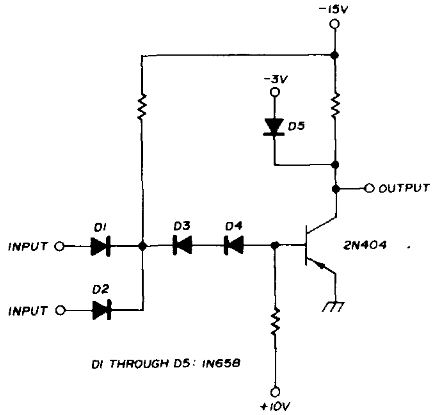


fig. 5. A DTL 2-input NAND gate using discrete components.

Similarly, by preceding each input of the NAND gate of an inverter, we create an OR gate, as in **fig. 8.** Note that this arrangement is just the opposite of the way we made the OR and AND functions with an RTL-NOR gate.

TTL logic

Transistor-transistor logic (TTL or T^2L) is a newer form of current-sinking logic. TTL was born in the IC age and has no discrete equivalent. A typical TTL two-input gate is shown in **fig. 9.** Note that the input transistor has two emitters. Each of these emitters acts much as one

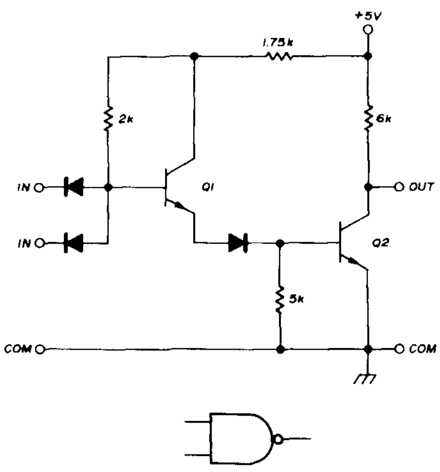


fig. 6. Example of current-sinking logic using ¼ of an MC846P DTL gate.

of the input diodes in a DTL gate to control the single input transistor.

Since TTL is also a current-sinking logic, and also operates on V_{cc} = +5 V, the logic levels are compatible with DTL. In general, TTL is faster than DTL, which imposes some restriction on the mixing of the two families, but at lower speeds they are compatible.

There are five major TTL families on the market today: Texas Instruments SN7400N, Sylvania SUHL, Fairchild TTμL9000, Motorola MC3000-4000, and Signetics DCL.

SN7400N and variations. The SN7400N line was originally produced by Texas Instruments, but most of this line is second-sourced by other firms. There are about 200 members of the SN7400N series, and many more variations. Varia-

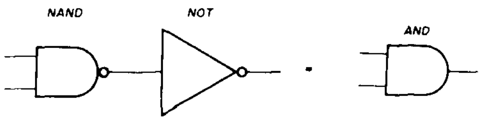


fig. 7. Formation of an AND gate using a NAND gate and an inverter.

tions are SN7400, SN5400N, and SN5400. The SN7400N is a plastic dual-inline package, SN7400 is a ceramic flat-pack, SN5400N is a plastic dual-inline package with MIL temperature specs, and SN5400 is a ceramic flat-pack with MIL spec temperature ratings.

In addition to the plastic dual-inline package, if one changes the N to a J at the end of the device number, the dual-inline package becomes ceramic. Further, if one puts an L between the SN74 and the next 2 or 3 digits, one gate is a lower-power version. If one puts an H in that same position, he gets a high speed version; and if an S is inserted, the ultra-high-speed Schottky version is specified that will toggle to 100 MHz. This method of variation is quite logical and creates a large variety from which to choose.

Design considerations. So that the electronic designer can "shift gears" when adapting older DTL systems to TTL, Texas Instruments has devised a dual nomenclature system. Thus a quad 2-input gate is called both SN7400N and SN74-846N, so that the designer knows it has pin-for-pin compatibility (in addition to logic-level compatibility), which enables him to substitute SN7400N logic for μL930 logic on an etched circuit board with no changes (in many cases). Further, since TI also makes the μL930 DTL line, a family-to-family fan-in, fan-out number system is available.

In general, DTL can drive 8 DTL loads or 5 TTL loads; TTL can drive 10 TTL loads or 10 DTL loads. The DTL equivalent of the SN7400N, SN74-846N is (sensibly) the SN15-846N, for instance, if one is specifying TI parts. The L, H, and S versions of the SN7400N family (low power, high speed, and Schottky-clamped, respectively) are not as numerous as the standard series units, nor are they widely second-sourced.

In general, all the TTL families are compatible with each other (and with DTL). Details and pin arrangement are the biggest differences, but then details must be observed even when one is designing within one logic family.

HTL logic

A special variety of DTL used with higher supply voltage than the μL930

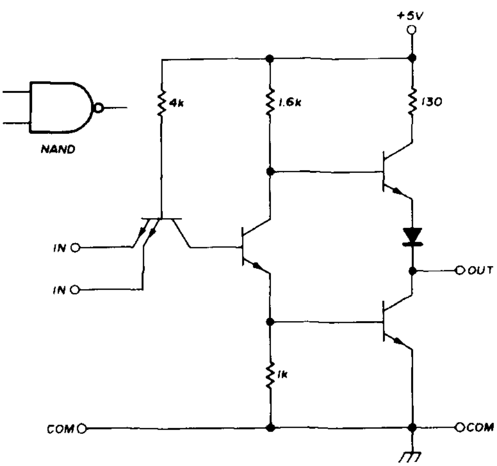


fig. 9. Typical 2-input TTL NAND gate consisting of ¼ of an SN7400N.

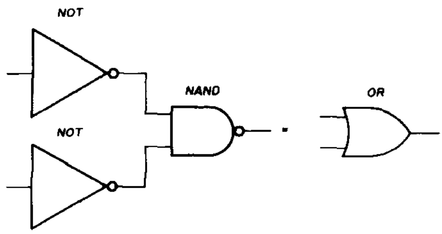


fig. 8. NAND gate inputs preceded by inverters equals an OR gate.

DTL is HTL (high-threshold logic). This family is, strictly speaking, offered only by Motorola, but HNIL (high-noise immunity logic) by Amelco Teledyne is essentially the same, as is HLLDTμL (high logic level diode-transistor micrologic) by Fairchild. These families all have the standard multiple diode inputs of DTL as shown in **fig. 10.**

Comparing **fig. 10** with **fig. 6**, we see the really important difference between these two DTL forms: the diode coupling Q1 and Q2 in **fig. 6** is replaced by a zener in **fig. 10.** This causes the HTL to have a much larger noise immunity. For this reason, HTL is often used in systems that contain electrically noisy components like relays and brush-type motors.

If we stick to V_{cc} of 12 to 15 volts, all these high-level families are compatible. The HNIL line will not operate above +15 V, however, as will the Motorola and Fairchild versions. All these HTL families have interface units available. Amelco and Motorola level-shift units will interface (either way) with DTL/TTL or RTL. The Fairchild level-shift units will interface only with DTL/TTL (either way).

ECL logic

Emitter-coupled logic (ECL) is the only bipolar IC logic form that does not use transistors that flip between the nonconducting and saturated states. This nonsaturated logic, also referred to as current mode logic, was pioneered by Motorola. Motorola has produced four series of MECL (Motorola emitter-coupled logic): MECL I, MECL II, MECL III, and MECL 10,000. MECL I operated at speeds up to 30 MHz, MECL II operated at speeds up to 120 MHz, MECL III operates up to 350 MHz, and MECL 10,000 has lower power consumption but speed similar to MECL II and III. MECL I and II are second-sourced by Stewart Warner in pin-for-pin equivalents. RCA,

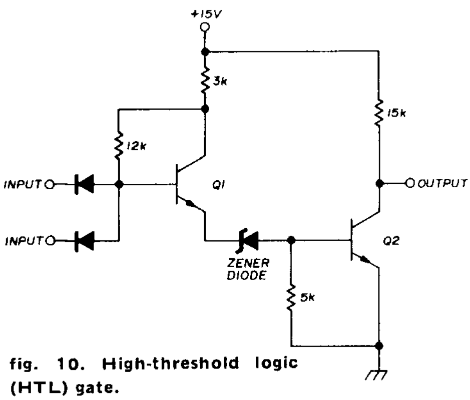


fig. 10. High-threshold logic (HTL) gate.

Fairchild, and Texas Instruments also offer their own lines of ECL, which have logic levels compatible with the Motorola family.

The curious thing about ECL is that the V_{cc} lead is usually grounded and the V_{ee} lead operated at -5.2 volts, yet ECL uses positive logic. Having the ECL units operating below ground makes ECL and other logic families awkward to operate together, because of the requirements for both positive and negative power supplies.

There are several logic-level translators available to interface ECL and DTL/TTL. MECL I has the single translators MC317 and MC318; MECL II has the single-level translators MC1017 and MC1018 plus the quad translator (MECL to DTL/TTL only) MC1039. There are no MECL III translators because there are no saturated IC logic families that can operate at speeds above about 100 MHz.

An ECL gate is shown in **fig. 11**; note R_e, the emitter resistor, from which the logic derives its name. The basic ECL gate is a differential amplifier, with the base of Q2 referenced to -1.15 volts. Since this differential pair is used in logic applications, either Q1 or Q2 is on. Since ECL uses positive logic (as do the other logic families we've already looked at), 1 = -0.075 V and 0 = -1.55 V. If either Q1 or Q1' are in the 0 condition, then RC2 draws all the current. In either case, the total current drawn by the pair is nearly constant.

Since there are two outputs in opposite states, this form of logic gate offers both NOR and OR functions as a basic part of its circuit. This feature is quite useful and can save the addition of extra inverters.

As seen in **fig. 11**, each output has an emitter follower built in to provide better fan-out. The typical fan-out of ECL is 15, which is considerably larger than most other logic families. Because fan-out from standard ECL units is so large, no buffer gates are offered. **Fig. 12** shows a Motorola MC306G in combination with a Motorola MC304G bias driver. The bias driver is simply a source of regulated reference voltage.

In the MECL II, III, and 10,000 lines, the bias driver is built into the gate chip, so no external source of V_{bb} is needed. Also, since the bias driver is built in, and the units are available in a plastic DIP, MECL II is generally less expensive than MECL I.

MOS logic

Another category of IC logic is the metal-oxide semiconductor (MOS). I avoid calling MOS a family, because no one company's MOS catalog has an industry-wide acceptance. The result of the absence of a dominant MOS logic family is chaotic – every company has its own particular idea as to what process makes the best chips.

There are some general things that can be said about the various MOS ICs, however. Most of them operate on a negative V_{dd} of -10 V to -40 V, therefore having negative logic (where 0 = 0 volts and 1 = a more negative voltage). They are generally slower than bipolar ICs and are well adapted to large-scale integration (LSI) because of the ease of getting a large number of MOS circuits per unit area on the chip.

Because MOS is so well adapted to LSI, wherein we are talking of hundreds or thousands of gate sections per chip, and because no dominant MOS family has emerged, we find that MOS is mostly available as large arrays, such as memories. A few companies, like Fairchild, offer individual logic circuits such as 3-input gates, 5-input gates, and dual flip-flops as building blocks. That is, these building blocks are offered specifically for the engineer who is mocking up a breadboard for a custom-made array.

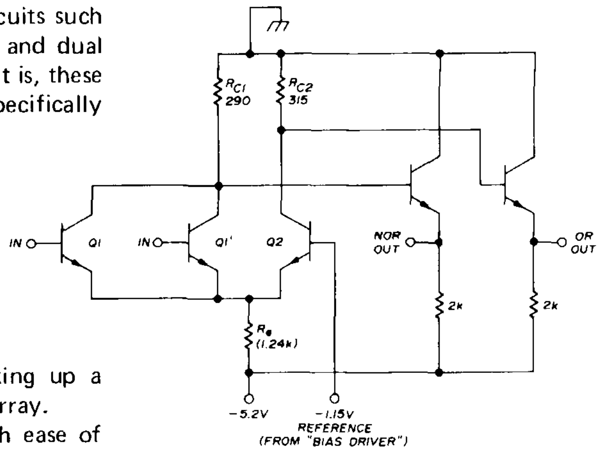


fig. 11. Emitter-coupled logic (ECL) gate.

One reason MOS offers such ease of LSI construction is that all the elements on the chip are tiny fets. Some are used as resistors and some as fets, but all are similar types. As an example, **fig. 13** shows a Fairchild 3102 three-input gate and how it can be used as a NOR gate, NAND gate, or how two units can form an RST (set-reset) flip-flop. The cost of the 3102 is $6.00 compared with an SN7410N triple 3-input gate at $0.60 (TI-TTL). It's no wonder MOS isn't used for small logic systems, since the cost per gate is quite high. However, in an LSI array the cost per gate can drop to pennies in production quantities.

CMOS logic

A new type of MOS logic that's gaining industry-wide acceptance is complementary MOS (CMOS). While conventional MOS logic owes its existence to the fact that many gates can be placed on one small chip, CMOS doesn't offer this advantage to as large a degree. The main selling point of CMOS is that it offers nearly zero standby power, the power drawn when the logic is in the 1 or 0 state. CMOS essentially draws current only during a transition from a 1 to a 0 or vice versa.

So, for logic systems that require low power, especially when fairly low data rates are to be handled, CMOS is very attractive. RCA was first to offer CMOS units, but now Motorola and others are also in the business, and the prices of these very fine logic ICs are likely to approach those of TTL as volume use develops.

CMOS operates on +5 to +15 V, as opposed to MOS, which operates on generally larger negative voltages. The +5 to +15 V supply voltage means that it's a simple task to interface CMOS with DTL, TTL, or HTL.

Fig. 14 shows a CMOS gate; note that it has in it both P-channel and N-channel mosfets. Like conventional MOS logic, the mosfets in CMOS logic are enhancement-mode types. This means they are like zero-bias triodes; they are non-conducting until the gate (grid) is forward biased. Enhancement-mode N-channel mosfets have been almost nonexistent as

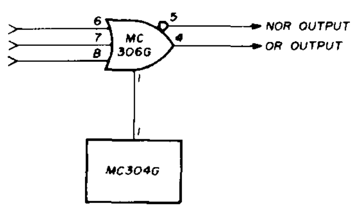


fig. 12. The MC304G bias driver provides a regulated reference voltage source for an MECL I gate.

discrete devices, which is probably why CMOS has become available only recently – i.e., a whole new MOS technology has had to be developed.

conclusion

We have looked at a number of logic families I feel are either common enough or inexpensive enough that amateurs will be likely to use them. There certainly are other logic families, which have been left out, because my intent was to present only the mainstream of IC logic; not the rare, expensive, or unique.

One often perplexing problem remains: that of interfacing logic families. Some comments on this have already been made in reference to ICs specifically made for family interfacing. The interfacing of RTL with DTL or TTL is fairly easy. My own preference is to use a μL900 (RTL buffer) to drive DTL or TTL from RTL. Driving RTL from DTL or TTL is usually direct; most DTL or TTL gates will provide enough voltage output to drive an RTL IC.

Interfacing ECL and DTL/TTL has been mentioned in the discussion or ECL. As expected, the same interface ICs that drive DTL/TTL from ECL are also useful to drive RTL from ECL. The usual case is not to drive ECL from the lower-speed logic families (RTL, DTL, and TTL). The units that drive DTL/TTL and RTL from

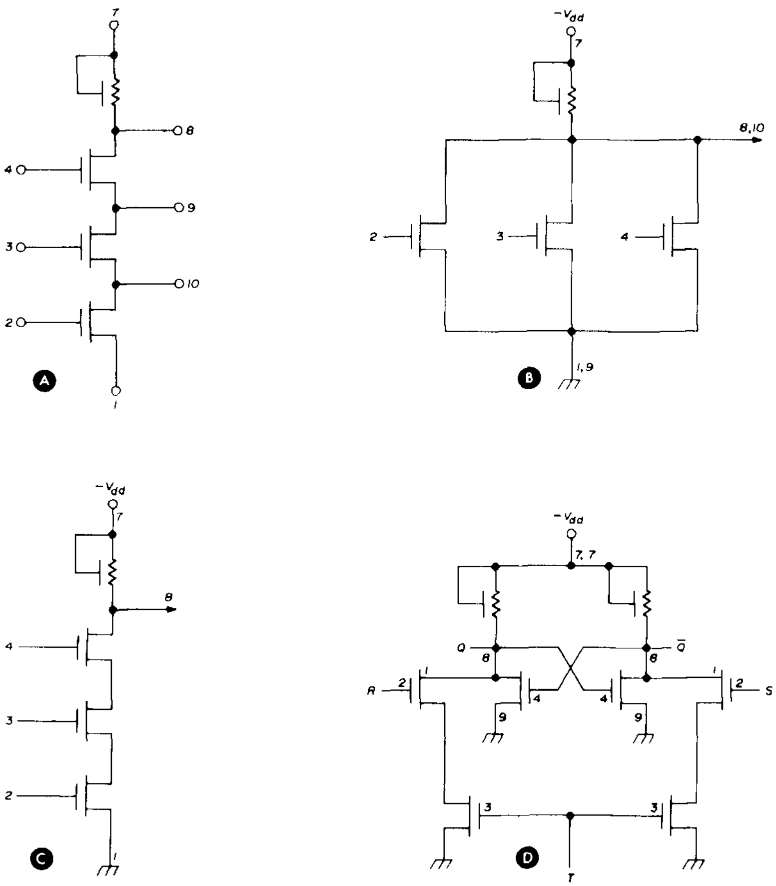


fig. 13. Fairchild 3102 3-input gate (A). A NOR gate, NAND gate, and RST flip-flop are shown in (B), (C) and (D).

ECL are MC317, MC1018, and MC1039. An example of the use of the MC1018 to convert between ECL and RTL is shown in reference 3.

There is even a readily available way to interface ECL and HTL. Motorola outlined this method at the 1969 series of digital integrated circuit seminars, using the MC1580. The method is shown in **fig. 15.**

The directly available DTL/TTL to HTL and RTL to HTL interface ICs have been mentioned in the discussion on HTL. These interface ICs can also be useful to drive some types of digital readout devices from RTL, DTL, or TTL.[4]

As pointed out in the discussion on MOS, there is no dominant MOS family yet; and so the interfacing of MOS with other logic forms is equally obscure – if not more so! In most cases the so-called bipolar-to-MOS interface circuits concentrate on converting the magnitude of shift from 0 to 1 and ignore the absolute values. This usually means that one ends up with the V_{ss} of the MOS portion of

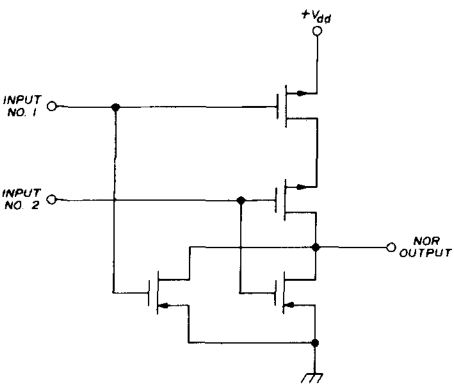


fig. 14. Complementary metal oxide semiconductor device (CMOS) 2-input NOR gate.

the circuit operating at +5 volts (when interfacing MOS and TTL) instead of at ground.

The interface may be constructed of discrete components as in reference 5. Several companies offer hybrid ICs that are quite similar to discrete-wired interface circuits, which are quite expensive compared to monolithic ICs.[6,7] Fairchild has a pair of ICs available that convert nicely from TTL/DTL to MOS or MOS to TTL/DTL; these are respectively 9624 and 9625. Texas Instruments also makes a rather versatile IC called the SN75450,

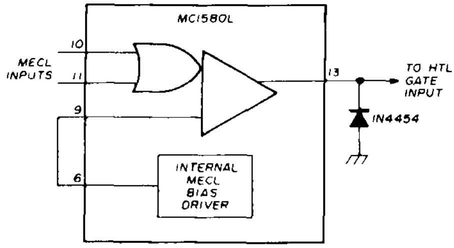


fig. 15. Interfacing MECL and HTL logic using an MC1580L.

which will interface MOS with TTL or vice versa. It requires a few external components, but it is very flexible.[8]

We've covered RTL, DTL, TTL, ECL, HTL, MOS, and CMOS families of IC logic in a sort of whirlwind fashion. Many logic ICs may also be used in circuits that are, strictly speaking, not logic functions, such as crystal oscillators. Many of the companies point up these uses in their data sheets, application notes, and handbooks.

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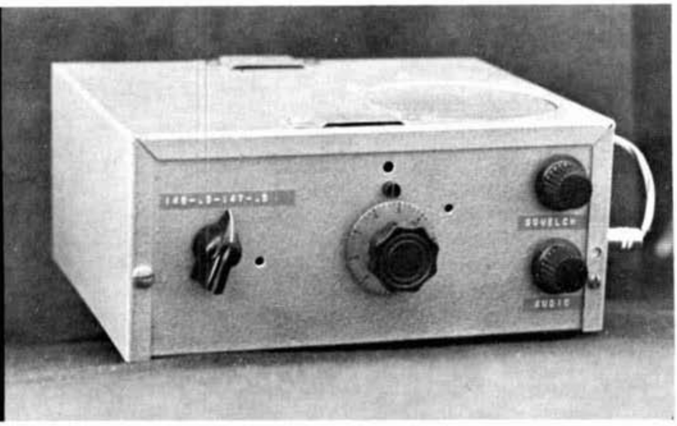

compact package

for two-meter fm

Design and construction details for a low-power fm transceiver for 144 MHz

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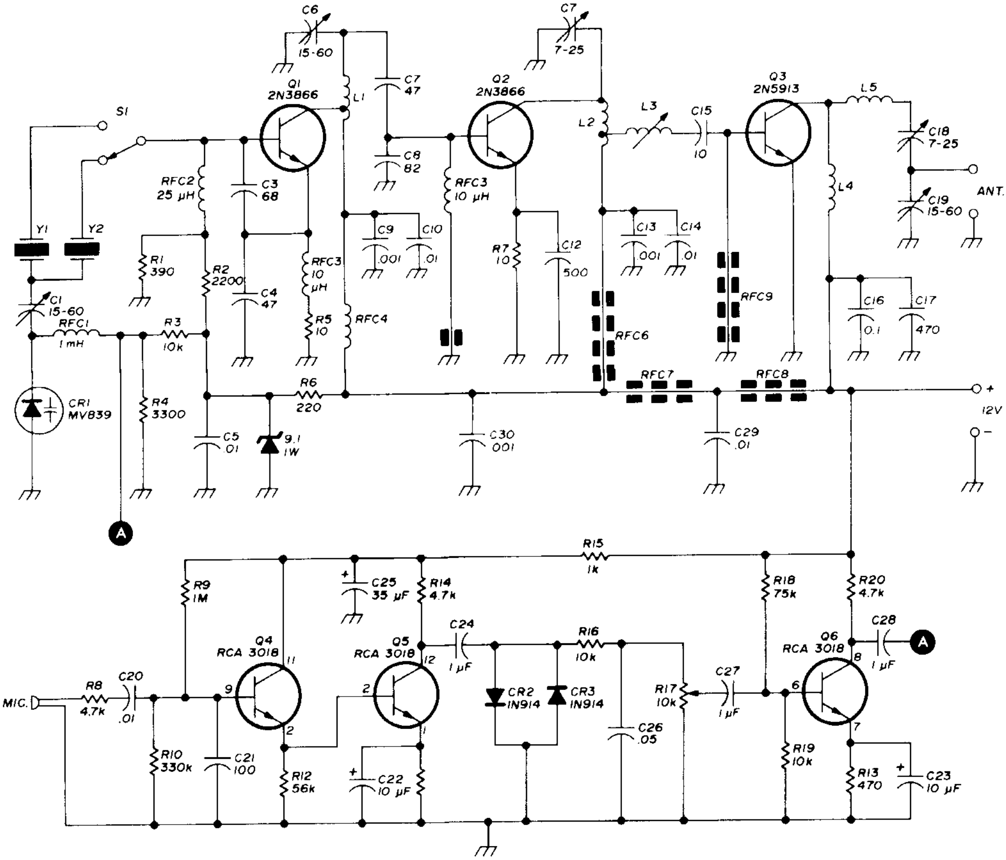
This article describes a compact package containing a low-power two-meter fm transmitter and a double-conversion, continuous-tuning fm receiver suitable for either fixed or mobile use. Although this description is primarily directed at the homebrew builder who balks at the cost of commercial equipment but lacks the time to develop his own design, the unit also includes several features which can be worked into different designs. The entire package, including everything but the power supply, is housed in a cabinet which is small enough to be accommodated in any automobile.

transmitter

Because this project is a combination of a previously described transmitter and an original receiver, design of the transmitter will be discussed first, and only with regard to certain minor changes and its performance. The transmitter is the Pip-Squeak, Mk II, described by W1CER.[1] The complete schematic is shown in **fig. 1** for reference to the



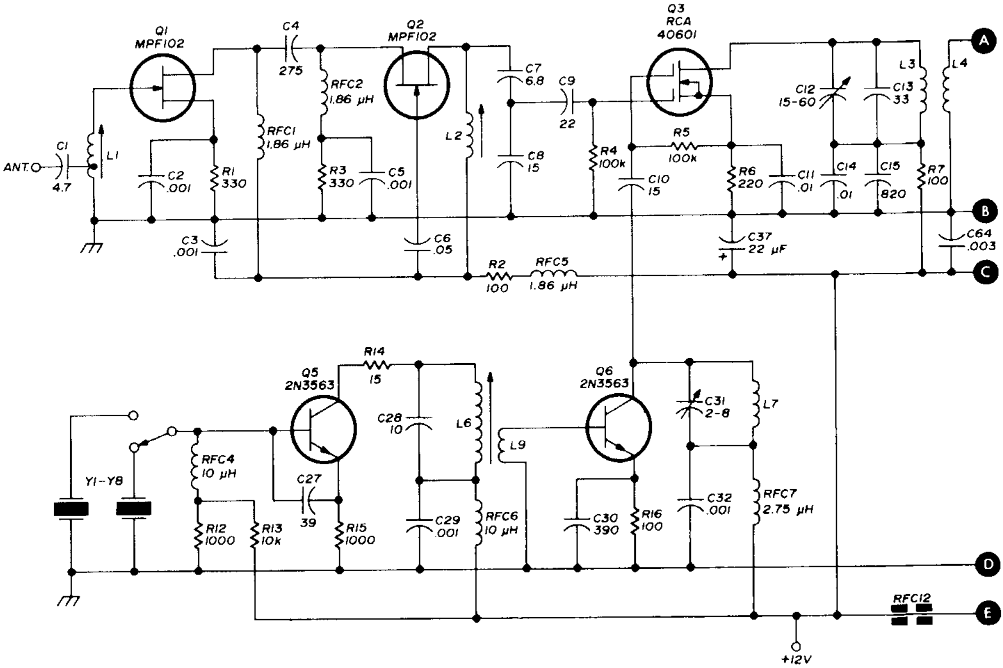
L1	5 turns no. 16 tinned bus wire, ¼" ID, 5/8" long, tapped at 2½ turns	L5	5 turns no. 16 tinned bus wire, 5/16" ID, ½" long
L2	3 turns no. 16 tinned bus wire, ¼" ID, 3/8" long, tapped ½ turn from C13 end	RFC6 RFC9	4 Amidon ferrite beads on ½" length of no. 24 wire
L3	4 turns no. 22 enamelled wire, closewound, ¼" ID	RFC7 RFC8	3 Amidon ferrite beads on ½" length of no. 24 wire
L4	25 turns no. 28, closewound on body of 100k, 1-watt resistor	Y1,Y2	18-MHz crystal ground for 20-pF load capacitance

fig. 1. Schematic for the two-meter fm transmitter. Transistors Q4, Q5 and Q6 are part of an RCA CA3018 IC.

changes mentioned above. In this circuit transistors Q4, Q5 and Q6 are part of an RCA CA3018 IC. Two 1N914 diodes should be used for symmetrical clipping rather than using the emitter-base junctions of transistors within the CA3018 IC.

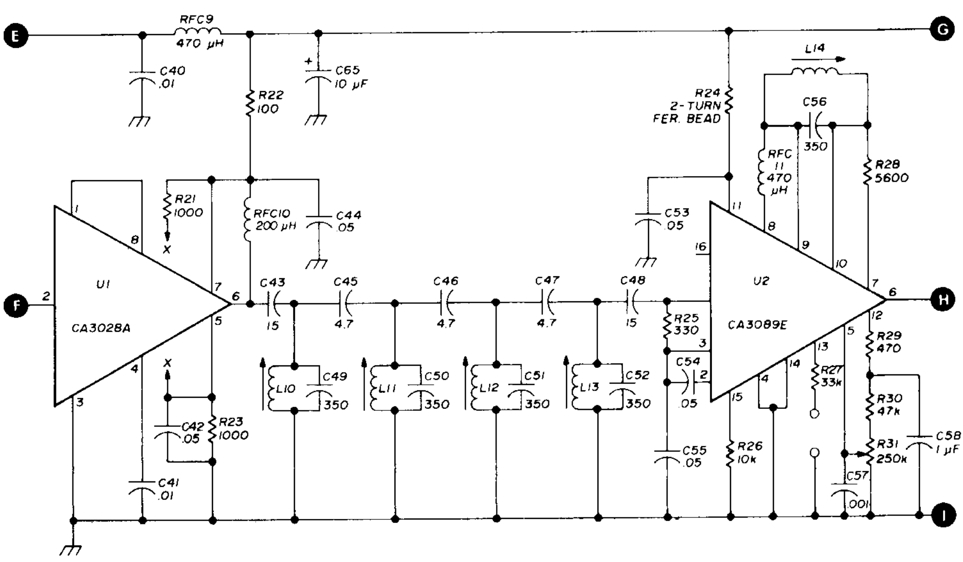
When building the unit, RFC5 and RFC9 should be placed on the foil side of the PC board. Emitter resistor R7 should consist of two ¼-watt resistors in parallel, dressed flat against the board for best stability. For further construction details, refer to the original article.

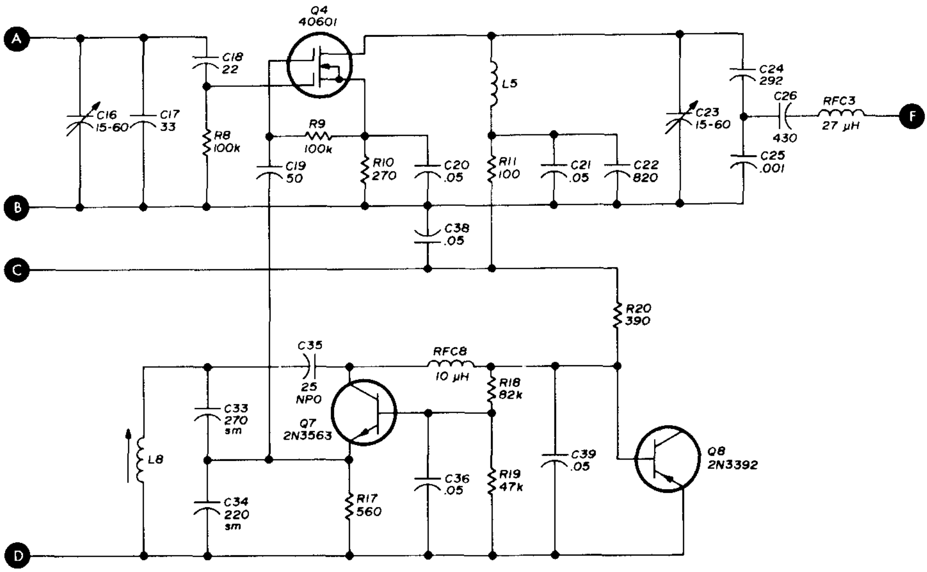
With these simple circuit changes, performance was easily duplicated in another transmitter which I built for a friend. The power output with a 12-volt power sup-



L1,L2	5 turns no. 20, ¼" ID, ½" long	L8	14 turns no. 32 closewound on 13/32" slug-tuned ceramic form (Millen 69041)
L3,L4	23 turns no. 30, closewound on 0.219" ceramic form (no slug), ¼" between windings	L9	2 turns no. 30 wound over cold end of L6
L5	38 turns no. 30 wound on 0.375" toroid core	L10,L11, L12,L13, L14	28 to 60 µH (J.W. Miller 9054)
L6	11 turns no. 28, closewound on 0.219" ceramic form		
L7	6 turns no. 20, ¼" ID, ½" long	RFC12	2 ferrite beads

fig. 2. Tunable, continuous-coverage receiver for two-meter fm.

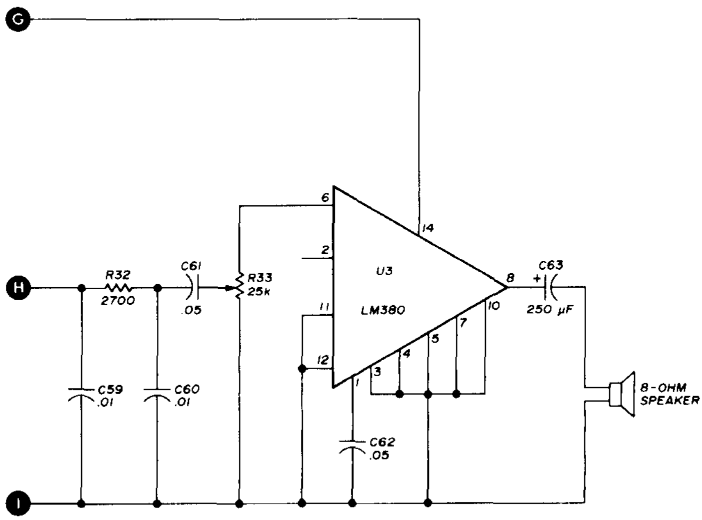


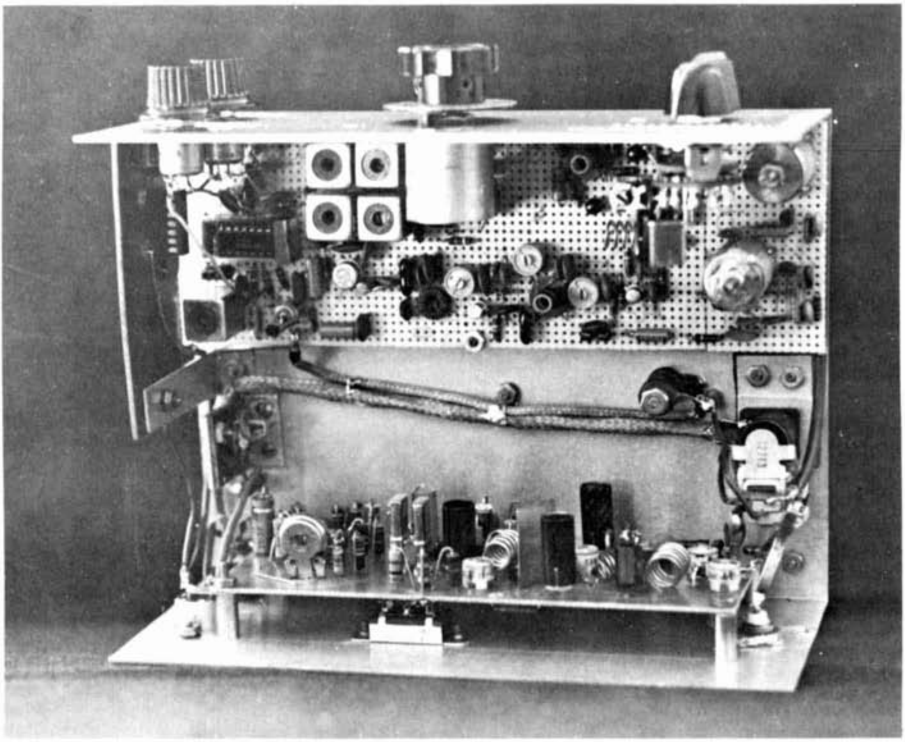


ply is about 1½ watts. This is sufficient to reliably trigger a local repeater from the mobile 10 miles away.

While the transmitter shown in the photographs uses only two crystals operated by a slide switch, it would be equally satisfactory to omit the crystal sockets on the PC board and replace the slide switch with a single external socket for use with any crystal you wish. Tuning can be compromised to use crystals whose two-meter outputs are 1 MHz apart.

The receiver input stage, consisting of transistors Q1 and Q2, is a cascode amplifier using fets. This circuit is particularly satisfactory in that it is not critical as to component values, other than the input and output inductors, it is completely stable and gives a voltage gain of 20 to 25 dB. The inductor shields, not intended to be helical resonators, are thin-wall brass tubes with 6-32 nuts soldered to the tops to permit using 3/16-inch tuning slugs for trimming to frequen-





Construction of the two-meter package. The transmitter section is mounted along the rear wall of the enclosure (bottom). The tunable receiver is laid out on perf board and mounted toward the front of the chassis (top). Transmit/receive relay is to the right.

cy. The tubes themselves are secured by wire pins, passing through the PC board and soldered to the foil side beneath.

The PC board is a standard Vector product, pre-punched in a rectangular grid of 0.10-inch spacing between holes, coated with 2-ounce copper foil on one side. This board is comparatively inexpensive and lends itself to circuit carving with high speed hand tools such as those made by Dreml, Casco, etc. The only drawback is that the board is only 6½-inches long, which required patching on the additional length required. The attractive feature of this type of PC board is that parts may be laid out on the top surface, adjusted to existing holes, interferences resolved and the necessary circuitry drawn in pencil first and then transferred to the foil side for engraving.

Returning to the circuitry, I decided that the second i-f should be somewhere near the top of the broadcast band for reasons which will be discussed later. Since I had also decided that continuous tuning of the entire two-meter band was desirable and practical, it quickly became apparent that 500-kHz segments would be a reasonable target if a medium high first i-f frequency were chosen.

In order that no harmonics of the second conversion oscillator fall into the two-meter band, it develops that the lowest tuning range of the second conversion oscillator must be in the 11.385 to 12.000-MHz range (13th harmonic of 11.385 MHz = 148 MHz, 12th harmonic of 12.000 MHz = 144 MHz). If the second oscillator is set to cover 11.440 to 11.940 MHz, the median frequency is 11.690 MHz. Subtracting the second i-f gives a median frequency of 10.230 MHz for the first i-f. Therefore, the first i-f bandpass range is 9.980 to 10.480 MHz which is comfortably clear of the commercial fm tuners i-f of 10.7 MHz.

This juggling of frequencies does not come by divine inspiration or revelation but happily turns out to be an acceptable solution which does not require extreme measures in the way of second oscillator stabilization.

With the first i-f established at 10.230 MHz and covering plus and minus 250 kHz, you can pick the frequencies for your crystals for the first conversion oscillators. For example, if you want to cover the band from 147.00 to 147.50 MHz, take the median frequency of 147.250, subtract the median i-f frequency of 10.230 MHz to get the first oscillator injection frequency of 137.020 MHz. This means you must order a third-overtone 47.673-MHz crystal and triple that to feed into the first mixer.

The first oscillator circuit is conventional, with its collector tuned to the third overtone of the crystal and driving the base of a second transistor operating as a tripler. Using a second transistor gives a cleaner injection signal and insures adequate drive for the mixer. The dual-gate mosfet mixer is greatly preferred over plain fet mixers with regard to overall performance and the amount of drive required. Tuning the oscillator tripler circuit permits establishing the optimum amount of required injection drive, and the mixer output can be significantly improved by such tuning.

The first mixer feeds the second mixer input through a pair of bandpass circuits. The second mixer is also a mosfet. Its output is tuned to the second i-f frequency of 1460 kHz. The output impedance is stepped down by a capacitive divider to match the low input impedance of the CA3028A IC. Drive to the CA3028A is applied through a series tuned circuit which provides the desired low impedance drive and also discriminates against any first i-f and second oscillator signals appearing in the second mixer drain circuit.

variable oscillator

The second oscillator, covering the tuning range of 11.440 to 11.940 MHz, was one of the major hurdles of the whole design. Capacitance tuning was tried, rather pessimistically, and I was not disappointed. As expected, it was noisy, tuning was much too critical and the capacitor occupied too much space. Next, I tried slug tuning the inductor with various slugs, both powdered iron and ferrite. This eliminated the noise but, with any reasonably compact coil, would not cover the desired tuning range.

Finally, a small Millen coil from the junk box was tried. This is a ceramic coil, 13/32-inch in diameter, ½-inch long with a threaded mounting boss, and tuned with a silver-plated slug, the threaded screw of which projects through the mounting boss (Millen part number 69041).

This coil form turned out to be a prime solution to the tuning problem. The required 500 kHz can be tuned in three turns, which gives adequate spread, and if the slug is properly positioned in the winding, tuning is nearly linear. (This is with the external 1-inch aluminum shield shown in the photographs. Without the shield, the tuning rate is much faster.) As indicated in the schematic, the collector voltage of this oscillator is zener regulated, using the base-emitter junction of a 2N3392 which regulates at 8.6 volts.

The maximum drift of the entire receiver, after two hours operation, is less than 20 kHz, i.e., 10 units on a 100 unit dial. How much of this is attributable to the tunable oscillator I don't know, and quite frankly, don't care. The tuning is smooth, absolutely noiseless and perfectly retraceable. The slug travel is established by the mechanical limit in the coil form at one end, and by positioning and locking a ¼-inch bakelite rod threaded on the slug screw. The tuning dial is on the bakelite rod.

The 1460-kHz output of the second mixer drives a CA3028A in cascode configuration strictly for gain purposes, which in turn feeds a 4-pole filter for high selectivity. This filter consists of four Miller pot-core miniature rf inductors. These inductors are available in a series of ranges, the type 9054 being the most suitable. The aluminum shields on these inductors must be removed to connect a miniature ceramic capacitor across the winding to provide a shielded tunable circuit. The shields must, of course, be replaced. This requires some study and care in handling. If the Miller 9054 is not available, other inductors can be used with appropriate size capacitors to insure that they can be tuned to the 1460-kHz i-f.

detection and audio output

From the above filter the signal goes to the CA3089 IC. This IC has been both touted and castigated. It is a multipurpose device of great potential, but is extremely intolerant of careless circuit board layout. Briefly, it can provide hard limiting for fm purposes, considerable gain, agc, afc, quadrature fm detection, audio output and — a violent headache. It also has a squelch output and provision for driving a tuning meter. The squelch output is very effective in handling ignition noise when operating mobile. Considerable information, in detail, on the CA3089 is available on request from RCA. It is recommended that anyone contemplating using this IC take advantage of this material.

While the CA3089 was developed for commercial fm reception, it seemed the better part of valor not to attempt using it at the 10.7-MHz level, in view of the reported difficulties in taming it. On the other hand, the internal capacitances in the device which sum up the limiting control are so small that I felt it would be self-defeating to try to use it at a frequency as low as 455 kHz. Hence, the choice of the top of the BC band for the second i-f. At this frequency CA3089 performance, while a little ticklish, is all that could be wished for. Limiting is good, the audio recovery of narrowband fm is excellent and the tuning meter output, either voltage-wise or current-wise, is as described.

The audio amplifier is the LM380 IC made by National Semiconductor. This is a 14-pin DIP that will give nearly 1.4 watts output with a 12-volt power supply. No peripherals are required other than signal input and output and power-supply connections! The LM380 has an optional connection for high frequency bypass and the device will drive an 8-ohm speaker through a capacitor. It does require a 6-square-inch heatsink for its full rating of 2 watts. The photographs show the heatsink (a piece of copper-clad phenolic board) with the IC mounted on it at the end of the receiver PC board. The coupling capacitor is mounted directly on the speaker. The miniature phone jack mounted on the heatsink board permits using either the speaker in the cabinet or a remote speaker. Of course, a remote speaker will require its own coupling capacitor.

With regard to additional items not mounted on the transmitter or receiver boards, there is a miniature closed-circuit phone jack below and behind the heatsink. This is a practical necessity for adjusting and loading the transmitter when first put into operation. A 500-mA meter on a miniature phone plug should be used. Above the meter jack is the power input jack to take a plug from either a car battery or from an ac-operated power supply. Below the power jack is the three-connector microphone jack. The lead from the audio input to the transmitter board is less than 1-inch long.

The push-to-talk microphone lead transfers the input power from receiver to transmitter via the relay seen at the other end of the cabinet. This relay is a two-pole double-throw affair salvaged from some surplus equipment, and is used both as the power transfer relay and the antenna switching relay. It is similar to the type (and size) of those found in Command Sets. Although it is stamped, "28 Vdc," it has a 300-ohm coil which indicates that it would be easy on the power supply. By adjusting the fixed stop on the armature to reduce the air gap somewhat, and by adjusting the relay contacts to make lighter pressure, it was possible to make this relay operate on 10.5 volts. This is not unique with these relays, others have been similarly treated. It is also possible to shim up the contact assembly on some types to reduce the armature air gap even more. This solved the problem of a suitable relay and the price was right. There is a fixed 100-ohm resistor connected in parallel with the receiver power input to equalize the loads in the transmit and receive positions when using a zener-regulated power supply, but it is not essential.

No-signal power drain is 60 mA at 12 volts in the receive position, kicking up another 100 mA or so with strong signal input. In the transmit position at 12 volts current drain, including relay current, is 350 to 425 mA. This economical power requirement is within the capability of portable battery supply.

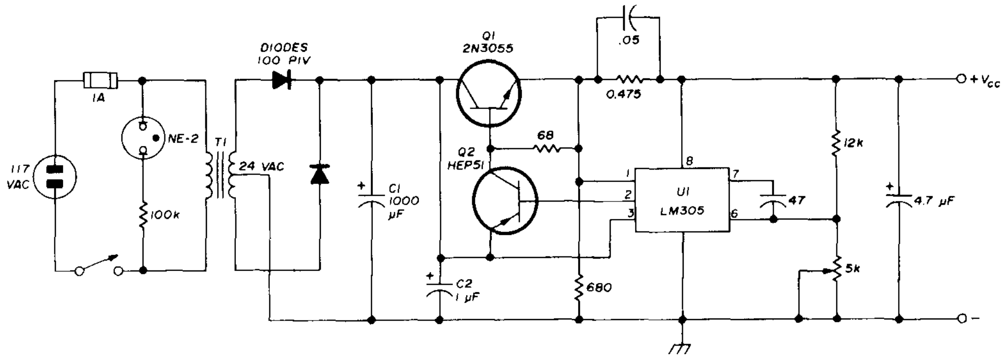


fig. 3. Ac power supply for operating the two-meter package at the base station.

converter

I have built a converter for a friend to be used with an automobile BC radio, using the rf amplifier, first mixer and first oscillator to give an i-f output in the 550- to 1550-kHz range. The converter board also contained a broadly tuned i-f transformer from a transistor radio which could be peaked to the approximate i-f, while the car radio is used as a tunable i-f and audio amplifier. With this arrangement two crystals can be used to cover half the two-meter band, the other half of the band appearing as a simultaneous image, not so confusing as might appear at first blush. One set of signals tunes up in frequency while the other tunes down. This unfelicitous arrangement comes out with a measured sensitivity of 2 microvolts, (lacking somewhat in selectivity) while the complete receiver comes off with a measured sensitivity of 0.8 microvolt.

alignment

Receiver alignment can be done with a CW signal except for final adjustment of the quadrature coil. First, disable both oscillators and open the series circuit to the CA3028A input. Feed a low-level 1460-kHz signal to the choke input to the CA3028A. Using a voltmeter on the CA3089 meter lead as indicator, peak the four inductors of the second i-f filter and adjust for equal response roll-off each side of the peak. Reconnect the series input to the CA3028A and shift the 1460-kHz signal input to the vicinity of the second mixer input and tune the second mixer output for maximum indicator response.

Remove the short from the second oscillator coil and tune the second oscillator to 11.690 MHz. Couple a low-level 10.230-MHz signal to the vicinity of the first mixer input and tune both bandpass circuits for maximum response. It may be necessary to resistively load one circuit for smooth response curve (don't forget to remove the loading when alignment is completed). Restore first oscillator operation and provide an appropriate two-meter signal to the receiver input.

Peak the output circuit of the cascode amplifier and then the input circuit. The former will peak sharply while the latter will have broad peak. Return to the first oscillator and adjust the tripler circuit to vary injection voltage to the first mixer for best response to a medium-strength signal. Finally, tune in an fm station on two meters and adjust the quadrature coil for best undistorted audio recovery. If you get on an active repeater frequency, you will have a variety of signal qualities to pick from.

ac power supply

A suitable power supply for fixed station use is shown in **fig. 3.** The LM305 voltage-regulator IC is in a TO-5 can. It provides excellent regulation and current limiting. With the value of R3 indicated it will limit at about 1 ampere. The 2N3055 should have a heatsink and it is desirable that Q2 and the IC also have heatsinks. The tantalum capacitors are specified as such by National Semiconductor as safeguards against parasitics in either the power supply or the load. With the component values shown in **fig. 3** the supply will provide 400 mA at 12.3 volts. The output voltage may be reduced considerably, for preliminary test purposes, by means of the 5k pot. All the components for the power supply, except the transformer and 1000-μF filter, can easily be accommodated on a 3-inch-square board.

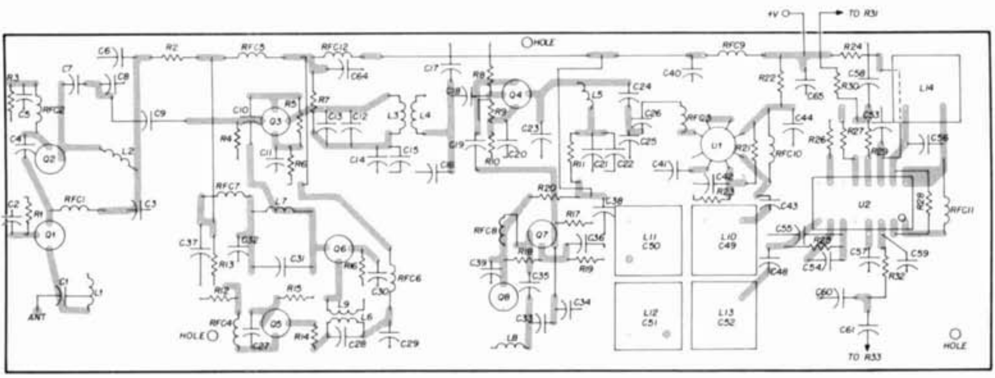


fig. 4. Printed-circuit layout for the tunable two-meter fm receiver. This layout is approximately two-thirds actual size.

summary

I don't expect that many amateurs will undertake a project of this magnitude on faith alone, but, hopefully, many readers can use some parts of the design. Some experience with the use of the high-speed carving tools is an absolute necessity.

One of the major problems of compact construction is the source of components. This applies particularly to the physically small items. One prolific source is surplus boards — assuming that the items are quickly identifiable by the seeker. The best source, by far, for new components is Newark Electronics in Chicago. However, you must have their industrial catalog available for ordering parts, and this approach is not inexpensive.

There is considerable satisfaction in operating equipment using solid state devices. In addition to compact size, light weight and low power requirements, there is the assurance that, barring mechanical damage, the performance will remain undiminished for the indefinite future. I have been very well satisfied with the performance of this equipment pending the time when some inventive soul produces a 10-watt vhf power transistor in a TO-5 can with integral heatsink. Then back to the drawing board!

reference

1. Doug DeMaw, W1CER, "The Pip-Squeak Gets Smaller," *QST,* September, 1972, page 37.

ham radio

More Details? CHECK—OFF Page 110

how to solve transistor heatsink problems

A complete discussion of transistor heatsinks and how to choose the one you need for your application

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How much heatsink is enough? That's a question which can be answered by whether or not the transistor survives when power is applied to the circuit, but this is an expensive way of finding the solution to heatsink design problems; a better way is to calculate heatsink requirements, and select a suitable heatsink using manufacturers' specifications, or make your own heatsink based on empirical data.

A heatsink problem is just one part o the larger problem of designing a tran sistor circuit to do a particular job; afte the performance requirements of the cir cuit have been established, answers to the following questions must be found. How much power must the transistor dis sipate? Will the selected transistor dis sipate this much power? If so, how much heatsinking is required?

estimating dissipation requirements

Power dissipated by the transistor is that power which is wasted in heating the transistor; it is equal to the power de livered to the transistor minus the power the transistor delivers to its load. A typical example is shown in **fig. 1.** The total power into the transistor is the sum of the signal power into the base plus the dc power delivered to the transistor by the power supply; power wasted in bias resistors does not count. Power delivered by the transistor to its load is the power into the output matching network.

Let's put some hypothetical numbers on the circuit of **fig. 1.** Let's say the amplifier is operated class A, dc collector current is 200 mA, V_{CC} is 12 volts, and the emitter voltage, V_E, is 2 volts. Let's further assume that there is no dc voltage drop in the primary of the output matching network. Therefore, the dc voltage from collector to emitter is equal to 12 minus 2, or 10 volts. With 200 mA of collector current, the dc power into the collector is

$$P_C = V_{CE} I_C = (10 \text{ volts})(0.2 \text{ amp}) = 2 \text{ watts}$$

If the dc beta, or current gain, of the transistor is 50, then the base current is

$$I_B = \frac{I_C}{B} = \frac{200 \text{ mA}}{50} = 4 \text{ mA}$$

Assume the base-emitter voltage of the transistor is 0.6 volt; then the dc power into the base will be

$$P_B = I_B V_{BE} = (4 \text{ mA})(0.6 \text{ volt}) = 0.0024 \text{ watt}$$

This is insignificant compared to collector power and may be neglected.

Assume the transistor delivers 0.9 watt of ac power to the output matching network, and the transistor has a power gain of 10. In this case the signal power into the transistor is

$$\frac{0.9}{10} = 0.09 \text{ watt,}$$

and total power into the transistor would be 2.09 watts. The transistor must dissipate the difference between total input power and output power, or

$$2.09 - 0.9 = 1.19 \text{ watt}$$

When the input signal is removed, however, the transistor must dissipate 2 watts because none of the power from the collector power supply goes into the load.

Class-B and class-C amplifiers can be handled in much the same way, the important difference being that the transistor does not dissipate appreciable power when the input signal is removed. Transistor dissipation will still be approximately equal to the difference between the dc power furnished by the collector power supply and the signal power delivered to the collector load.

Fig. 2 shows an example of a class-C rf amplifier. The dc power from the power supply is 2.4 watts, and the power into the T matching network is 1.5 watts. Therefore, the power which must be dissipated in the collector of the transistor is 2.4 minus 1.5 or 0.9 watts. If the power gain of the transistor is 10, then 0.15 watt must be fed into the base of

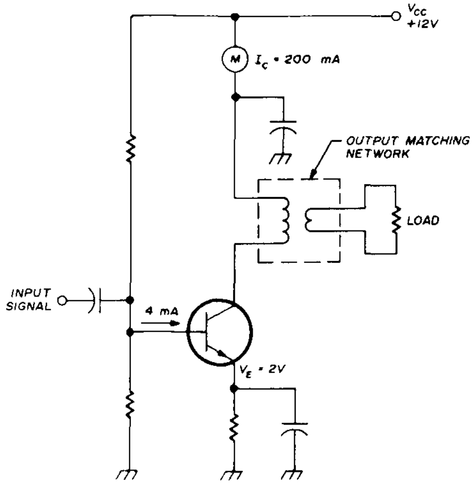

fig. 1. Class-A transistor power stage used to illustrate power dissipation (see text).

the transistor, making a total of 0.9 plus 0.15, or 1.05 watt, which must be dissipated by the transistor.

Transistors used in power supply regulators often require heat sinks. **Fig. 3** shows a simple regulator which delivers 12 watts to the load. Neglecting the transistor base current and zener diode current, the power into the regulator from the rectifiers is

$$18 \text{ volts} \times 1 \text{ amp} = 18 \text{ watts}$$

The transistor must dissipate the difference between input power and output power, or 6 watts.

transistor capabilities

After the power dissipation is estimated, a transistor may be selected which meets the power requirement; this is done by studying the data sheets of transistors which meet other circuit requirements such as gain and frequency range.

Most transistor data sheets show one or both of the following power ratings. One is total device dissipation at (or below) 25°C *free-air* temperature; this is the maximum power the transistor may dissipate without any heatsink if the temperature of the air around the transistor is 25°C or less.

The other rating is total device dissipation at (or below) 25°C *case* temperature; this is the maximum power the transistor may dissipate if the transistor case temperature is held to 25°C or less. One way to hold the case temperature at 25°C is to mount the transistor on a heatsink which has integral cooling coils through which ice water is pumped. This is rather expensive, however, and the usual procedure is to simply mount the transistor on a heatsink and allow air at room temperature (25°C) to circulate around it. This method will not hold the case temperature at 25°C, so a reduced power rating must be accepted for the device.

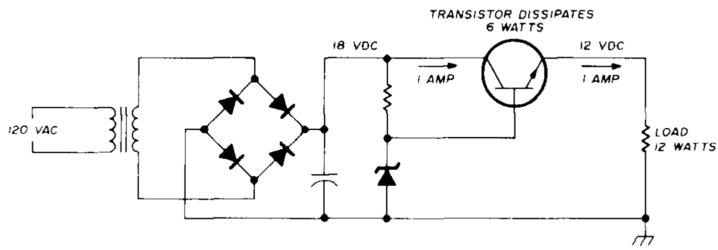

fig. 3. The series regulator transistor in this simple power supply dissipates 6 watts.

Included with the free-air and case-temperature ratings are derating factors which say that the device must be derated linearly to some temperature (free-air or case) at the rate of so many watts-per-°C. Derating factors may be shown as footnotes on the data sheet.

Some transistor data sheets include dissipation derating curves which are merely graphs showing what has already been specified; if the data sheet does not include it, one may easily be drawn. **Fig. 4** shows derating curves for the 2N3724A transistor. This device is rated for 1-watt dissipation at 25° C free-air temperature (no heatsink) with a derating factor of 5.71 mW-per-°C to 200°C. Notice that if the free-air temperature is 200°C, no power may be dissipated by the transistor. If the free-air temperature is 50°C. then the amount of derating is 25°C times 5.71 mW-per-°C, or 143 mW; this derating is subtracted from the 1-watt rating to find how much power may be dissipated at 50°C free-air.

$$1000 \text{ mW} - 143 \text{ mW} = 857 \text{ mW}$$

The case temperature curve applies if a heatsink is used. If the transistor dissipates, say 3 watts, then, according to **fig. 4,** the heatsink must be large enough to hold the case temperature to 95°C or less. Operation must always be on the curve or below it. It is good design practice to

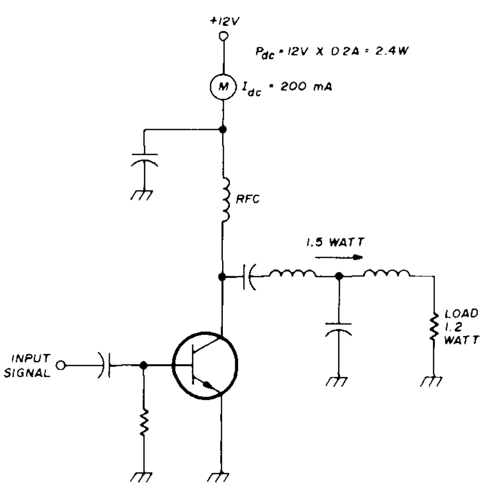

fig. 2. The transistor dissipates 1.05-watt in this class-C rf amplifier stage.

allow some safety factor by operating somewhat below the curve, i.e., use a slightly larger heatsink than is called for. As mentioned above, practical heatsinks will not hold the case temperature to 25°C, so you should not expect to operate this device at 5-watts dissipation.

Some transistors have power ratings specified at 50°C or 100°C case temperatures, with appropriate derating factors for case temperatures above those values. **Fig. 5** shows the derating curve for the 2N5387. This transistor is rated for 100 watts at (or below) 100°C case temperature and has a derating factor of 1 watt-per-°C to 200°C case temperature. It is possible for transistors with such ratings to dissipate their full power rating using an air-cooled heatsink, provided the heatsink is good enough.

thermal resistance

Thermal resistance is expressed in the units, °C-per-watt. This is the temperature difference that will occur between two points for each watt of power that is dissipated at one of the points, the higher temperature being at the point where power is dissipated. The reciprocals of the derating factors discussed above are thermal resistances.

$$\text{Thermal Resistance } \frac{°C}{\text{watt}} = \frac{1}{\text{Derating Factor } \frac{\text{watts}}{°C}}$$

Theta (θ) is the mathematical symbol used for thermal resistance, and subscripts are used to denote which two points the thermal resistance is between:

$\theta_{J\text{-}A}$ junction-to-ambient
$\theta_{J\text{-}C}$ junction-to-case
$\theta_{C\text{-}HS}$ case-to-heatsink
$\theta_{HS\text{-}A}$ heatsink-to-ambient

Junction is the term used for the point or points inside the transistor where the power is actually dissipated. Case means the point or points on the transistor package where the heatsink makes contact. Ambient is the medium into which heat is ultimately conducted or radiated, and it usually is free-air at 25°C.

If the transistor or heatsink is mounted inside an equipment cabinet

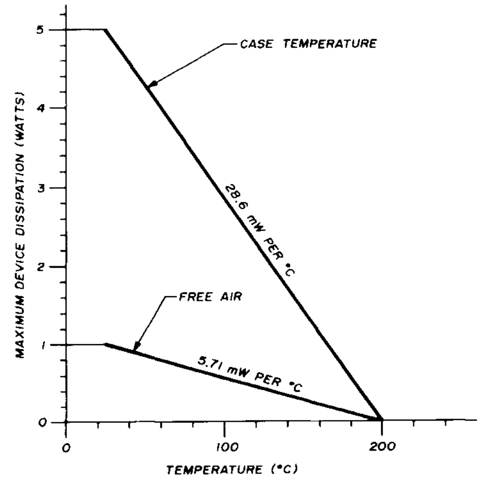

fig. 4. Dissipation derating curves for the 2N3724A transistor.

where the temperature is higher than room temperature due to heat-generating components, such as transformers, tubes, power resistors or the power transistor itself, then ambient means the temperature inside that cabinet. **Fig. 6** is a scale showing the relationship between °C and °F for those accustomed to expressing temperature in °F.

The reciprocal of the free-air derating factor is $\theta_{J\text{-}A}$

$$\theta_{J\text{-}A} = \frac{1}{\text{Free-air Derating Factor}}$$

For the 2N3724A (see **Fig. 4**),

$$\theta_{J\text{-}A} = \frac{1}{5.71 \frac{\text{mW}}{°C}} = 0.175 \frac{°C}{\text{mW}}$$

$$= 175 \frac{°C}{\text{watt}}$$

This thermal resistance value tells you how many °C the junction temperature will rise above ambient temperature for a given transistor power dissipation. If the ambient temperature, T_A, is 25°C, and 1 watt of power, P, is dissipated at the junction, then the junction temperature, T_J, will be

$$T_J = T_A + P\theta_{J\text{-}A} \qquad (1)$$

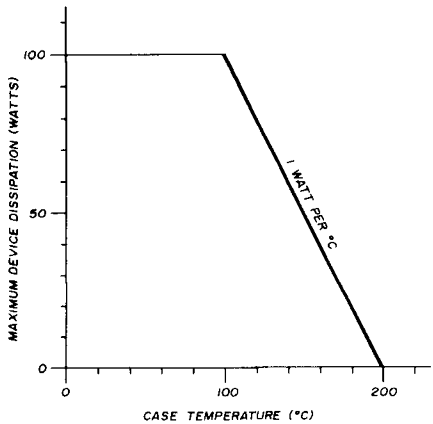

fig. 5. Dissipation derating curve for the 2N3724A transistor.

$$T_J = 25 + (1\ \text{watt})(175\ \frac{°C}{\text{watt}}) = 200°C$$

It is obvious from this and **fig. 4** that the maximum allowable junction temperature for the 2N3724A is 200°C. *The entire purpose of heat sinking is to prevent the junction temperature from exceeding the maximum allowable value specified by the manufacturer.*

Eq. 1 is the basic thermal equation used to determine if a certain power dissipation will cause the transistor's maximum allowable junction temperature to be exceeded. T_A should be the highest actual ambient temperature encountered. Don't use T_A = 25°C if the transistor is to be operated in the trunk of a car on hot summer days; 50 to 75°C would be more realistic.

When the transistor is fastened to a heatsink, $\theta_{J\text{-}A}$ breaks down into three quantities;

$$\theta_{J\text{-}A} = \theta_{J\text{-}C} + \theta_{C\text{-}HS} + \theta_{HS\text{-}A} \qquad (2)$$

Combining **eqs. 1** and **2** gives

$$T_J = T_A + P(\theta_{J\text{-}C} + \theta_{C\text{-}HS} + \theta_{HS\text{-}A}) \qquad (3)$$

$\theta_{J\text{-}C}$ is the reciprocal of the case temperature derating factor shown on the transistor data sheet;

$$\theta_{J\text{-}C} = \frac{1}{\text{Case Temperature Derating Factor}}$$

For the 2N3724A (see **fig. 4**),

$$\theta_{J\text{-}C} = \frac{1}{28.6\ \frac{\text{mW}}{°C}} = 0.035\ \frac{°C}{\text{mW}} = 35\ \frac{°C}{\text{watt}}$$

This value of thermal resistance tells you that the junction temperature will be 35°C higher than the case temperature for each watt of power dissipated in the junction. If 5 watts of power are dissipated in the junction, then the junction temperature will be 175°C higher than the case temperature. Therefore, the case temperature *must not* exceed 25°C if the junction temperature is not to exceed 200°C, its maximum allowable value.

Case-to-heatsink thermal resistance, $\theta_{C\text{-}HS}$, depends on several varying factors. How much torque is used in tightening the nuts or screws which hold the transistor to the heatsink? How smooth are the mating surfaces of the transistor and heatsink? Is the heatsink anodized? Is an insulating mica washer used between the transistor and heatsink? Is a silicone grease, or other thermal compound, applied to the mating surfaces? How and to what extent do these factors affect $\theta_{C\text{-}HS}$? All these factors have an effect.

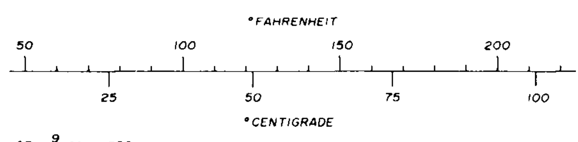

fig. 6. Relationship between the Centigrade and Fahrenheit temperature scales.

A mica washer will increase the thermal resistance about 0.3 °C-per-watt, and thermal compounds may decrease the thermal resistance about 0.1 to 0.2 °C-per-watt. Anodized surfaces are about 0.25 °C-per-watt higher than unfinished surfaces. A fair rule-of-thumb is to allow

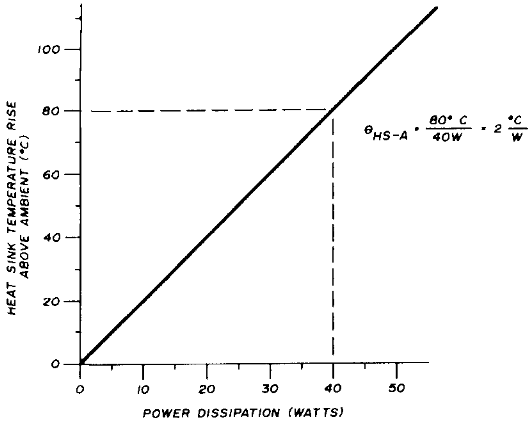

fig. 7. Typical heatsink performance curve.

about 0.2 °C-per-watt for $\theta_{C\text{-}HS}$ when the mating surfaces are bare metal; 0.5 °C-per-watt should be used if the heat sink is anodized or a mica washer is used.

$\theta_{C\text{-}HS}$ is usually not very significant at moderate power levels, but if the power dissipation is 100 watts, the temperature difference between the transistor case and the heatsink could be on the order of 50°C. Mating surfaces should be smooth and clean, and the transistor should be mounted tightly to the heatsink.

The last term in **eq. 3**, $\theta_{HS\text{-}A}$, is the heatsink-to-ambient thermal resistance. Heatsink manufacturers may specify the thermal resistance of their heatsinks in °C-per-watt, or they may provide a performance graph such as shown in **fig. 7**. Since the curve is usually a straight line, the slope of which is thermal resistance, $\theta_{HS\text{-}A}$ may be derived from the curve as shown. The manufacturer may label the vertical axis in **fig. 7** case temperature rise above ambient in °C; in this case $\theta_{C\text{-}HS}$ is included in the heatsink rating, so the slope of the line is equal to $\theta_{C\text{-}HS}$ + $\theta_{HS\text{-}A}$.

finding the right heatsink

To choose a suitable heatsink it is necessary to determine the value of $\theta_{HS\text{-}A}$ you need, then select a heatsink having that value, or less, of thermal resistance. Some examples will illustrate.

Suppose a circuit includes a TIP29 power transistor; the maximum power, P, which the transistor must dissipate is 15 watts. To allow for operation in non-air-conditioned places on hot summer days, ambient temperature, T_A, is assigned a value of 50°C. The TIP29 data sheet specifies that the maximum continuous device dissipation at (or below) 25°C case temperature is 30 watts, and this rating is to be derated to 150°C case temperature at the rate of 0.24 watt-per-°C. Thus, the maximum allowable junction temperature, T_J, is 150°C, and the junction-to-case thermal resistance is

$$\theta_{J\text{-}C} = \frac{1}{0.24 \frac{\text{watt}}{°\text{C}}} = 4.17 \frac{°\text{C}}{\text{watt}}$$

It is desired to use an insulating mica washer when mounting the TIP29 to its heatsink, so $\theta_{C\text{-}HS}$ is assumed to be 0.5°C-per-watt. All of this information is substituted into **eq. 3** as follows

$$T_J = T_A + P(\theta_{J\text{-}C} + \theta_{C\text{-}HS} + \theta_{HS\text{-}A})$$

$$150 = 50 + 15(4.17 + 0.5 + \theta_{HS\text{-}A})$$

Solving for $\theta_{HS\text{-}A}$,

$$\theta_{HS\text{-}A} = 2 \frac{°\text{C}}{\text{watt}}$$

Thus, an acceptable heatsink would be one which has a thermal resistance of 2 °C-per-watt or less. Armed with this information, you can quickly select a suitable heatsink from the manufacturers' catalogs. The Thermalloy Company's 6123 heatsink is rated at 1.3 °C-per-watt and would be quite adequate.

As a second example, assume a 2N5387 (see **fig. 5**) must dissipate 100 watts, and the ambient temperature is 25°C. From **fig. 5**, or from the derating information, the maximum allowable junction temperature is 200°C, and the junction-to-case thermal resistance is

$$\theta_{J\text{-}C} = \frac{1}{1\,\frac{\text{watt}}{^{\circ}\text{C}}} = 1\,\frac{^{\circ}\text{C}}{\text{watt}}$$

The transistor is to be mounted directly to the bare metal of the heatsink, so $\theta_{C\text{-}HS}$ is taken to be 0.2 °C-per-watt. Plugging these values into **eq. 3** gives

$$T_J = T_A + P(\theta_{J\text{-}C} + \theta_{C\text{-}HS} + \theta_{HS\text{-}A})$$

$$200 = 25 + 100(1 + 0.2 + \theta_{HS\text{-}A})$$

Solving for $\theta_{HS\text{-}A}$ yields

$$\theta_{HS\text{-}A} = 0.55\,\frac{^{\circ}\text{C}}{\text{watt}}$$

The Thermalloy 6560B heatsink should handle the requirement. It is a black anodized heatsink, but the catalog information indicates that for 100-watts dissipation, the transistor case temperature will be 45°C above ambient. This means

$$\theta_{C\text{-}HS} + \theta_{HS\text{-}A} = \frac{45^{\circ}\text{C}}{100\text{ watts}} = 0.45\,\frac{^{\circ}\text{C}}{\text{watt}}$$

Putting this into **eq. 3**,

$$T_J = T_A + P(\theta_{J\text{-}C} + \theta_{C\text{-}HS} + \theta_{HS\text{-}A})$$

$$T_J = 25 + 100(1.0 + 0.45) = 170^{\circ}\text{C}$$

which is 30°C less than the maximum allowable junction temperature; it would be unnecessary to remove the anodize where the transistor mounts to the heatsink.

homemade heatsinks

Heatsinks may be improvised by using sheet metal. Weight, volume and shape play some part in heatsink effectiveness, but exposed surface area is the prime factor on which thermal resistance depends. **Fig. 8** is a graph showing approximate $\theta_{HS\text{-}A}$ vs area of one side for 1/8-inch thick square aluminum and copper sheet metal. This data applies to square plates mounted so the plane of the plate is vertical, with the transistor fastened to the center of the plate.

The thermal conductivity of copper is nearly twice that of aluminum which explains why copper gives better results. Brass has a thermal conductivity about one-half that of aluminum, and should be avoided; steel is poor also. Aluminum is the best compromise between performance and cost, and it is widely used.

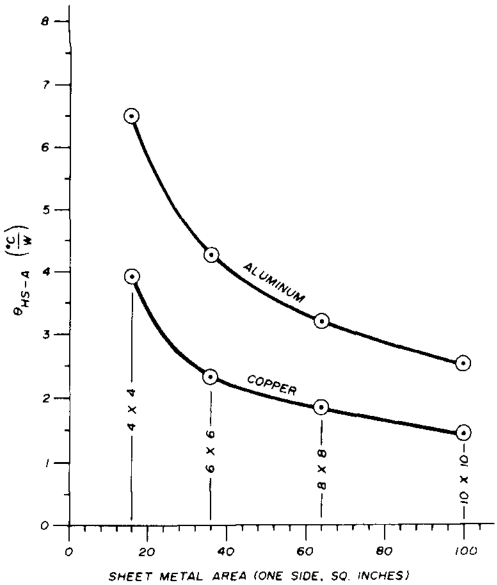

fig. 8. Thermal resistance vs area of 1/8" thick sheet metal.

Fig. 8 may be used to estimate the size of sheet metal needed after the required value of $\theta_{HS\text{-}A}$ has been determined. An aluminum chassis may be used as a heatsink by mounting the transistor to it, but the horizontal portion of the chassis does not get rid of heat as well as the vertical portions. Air rises when it is heated, and all heatsinks should be mounted so most of the surface area is vertical. This permits the most efficient flow of air past the heatsink due to convection currents.

forced air cooling

Blowing air across the surface of a heatsink by means of a fan or blower can dramatically improve the heatsink's performance. For example, air blown at a velocity of 500 feet-per-minute will reduce $\theta_{HS\text{-}A}$ to around one-third to one-half its still-air value; this corresponds to a light breeze of about 5.7 miles-per-hour.

Fans and blowers are rated in cubic feet-per-minute (cfm). To determine the approximate velocity of air out of a blower, the cfm rating is divided by the cross-sectional area of the blower's output hole. For example, suppose a small blower is rated at 20 cfm, and its output hole is 2 x 2 inches. The cross-sectional area is 4 square inches, or 0.0278 square feet, so the output air velocity is

$$\frac{20\text{ cfm}}{0.0278\text{ sq ft}} = 720\ \frac{\text{feet}}{\text{minute}}$$

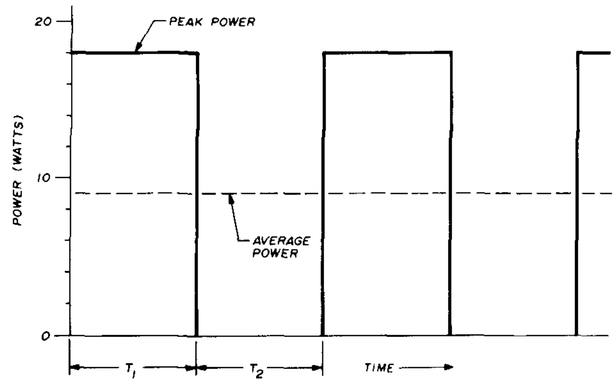

fig. 9. Power dissipated in a junction by a square wave.

If the blower cannot be mounted so that its output flows directly onto the heatsink, ducting may be used to channel the air stream to the heatsink. More detailed information on forced-air cooling may be found in heatsink catalogs.

thermal time lag

A finite amount of time is required for the junction temperature to rise to its steady-state value after power is applied. This fact allows the transistor to operate at higher ac peak power ratings than is possible at dc. **Fig. 9** shows a graph of the power dissipated in a transistor junction by a square wave; peak power is 18 watts, and average power is 9 watts.

Assume that the transistor and its heatsink are such that only 10 watts of power may be safely dissipated. If the frequency of the square wave in **fig. 9** is 500 kHz, T_1 and T_2 will each be 1 microsecond. The thermal time constant of most power transistors is large compared to 1 μs, so the junction temperature will be determined by the average power dissipation of 9 watts, and the junction will operate within its rating.

Now suppose the frequency of the square wave is decreased to a very low value, say one cycle-per-hour; T_1 and T_2 would each be 30 minutes, and 18 watts would be applied to the junction for 30 minutes during the first cycle, quickly destroying the device. This is an extreme example, but it points out the necessity of taking frequency into consideration when determining heatsink requirements.

Many power transistors have thermal time constants such that the use of average power in **eq. 3** would lead to an inadequate heatsink at the lower audio frequencies. Therefore, it is not a bad idea to use peak power in **eq. 3** for audio frequency applications.

Some transistor data sheets show a family of curves to be used in adjusting the value of $\theta_{J\text{-}C}$ according to pulse width and duty cycle, and these should be studied and used when available.

conclusion

It is hoped that this article will introduce the reader to the basic concepts involved in solving transistor heatsink problems; these principles may also be applied to other semiconductor devices such as thyristors and power zeners. More insight into heatsink technology may be derived by studying power transistor data sheets and heatsink catalogs. **ham radio**

simple lowpass filter for audio

This simple lowpass audio filter provides high performance and a minimum of design effort — a design graph is provided

Frank Regier, OD5CG, American University of Beirut, Lebanon

Lowpass audio filters have many applications in amateur radio, such as restricting transmitter bandwidth and establishing the bandwidth of direct-conversion receivers. Simple tee- and pi-section filters are often used in these applications but do not provide sharp cutoff. The circuit presented here is substantially better than a tee or pi but is nevertheless inexpensive and simple to build.

So-called modern filters are the best that can be made for a given number of components, but these components are likely to have awkward, nonstandard values. The filter to be described here performs very well and is much easier to make than a comparable modern filter. It consists of three unmodified telephone toroids and four identical capacitors — nothing more.

The filter is composed of a constant-k pi-section with an m-derived half-section at each end. For best matching to a resistive load, such half-sections are usually made with m = 0.6. If, however, you let m = 0.5, for only a slight degradation in performance you achieve two important simplifications. First, all capacitors in the circuit assume the same value, and second, each end inductor assumes exactly one-quarter of the value of the center inductor. This latter property makes it possible to use an 88- or 44-mH telephone toroid for the center inductor and half of a similar toroid for each of the end inductors. The resultant filter is shown in **fig. 1.** It is important that it be terminated in its proper load resistance, R.

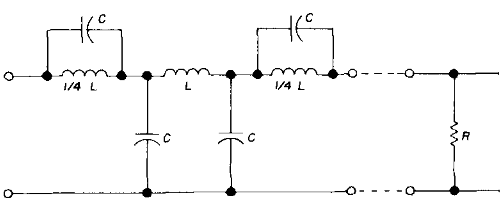

fig. 1. Simple lowpass audio filter uses three inductors and four capacitors. For L = 88 mH, the values of R and C may be obtained from fig. 2.

design

The design of a particular filter begins with the choice of a cutoff frequency. Then, with the value of L known, the values of R and C are obtained from the equations

$$R = \pi L f_c \text{ ohms} \quad (1)$$

$$C = \frac{0.75}{\pi^2 L f_c^2} \text{ farads} \quad (2)$$

where L is in henrys and f_c is the cutoff frequency in Hz.

If 88-mH toroids are used, the values of R and C may be obtained graphically from **fig. 2** for a considerable range of cutoff frequencies. For 44-mH toroids, the values of R should be half, and the values of C double, those shown in **fig. 2.**

To test the design, a filter was built using L = 88 mH and C = 0.1 μF. These values lead to a cutoff frequency of 2940 Hz and require a load resistance of 812 ohms. Each of the two 22-mH end inductors was formed by paralleling the two windings of an 88 mH telephone toroid. These toroids have very low core losses at audio frequencies, so their Q is determined almost entirely by winding resistance. The Q of the end inductors can therefore be almost doubled, without changing the inductance, if the two windings are paralleled. For correct polarity, the two braid-covered ends should be joined, and the other two ends should also be joined. The four capacitors were matched to within 1%, and a load resistance accurate to within 1% was made by paralleling higher-value resistances.

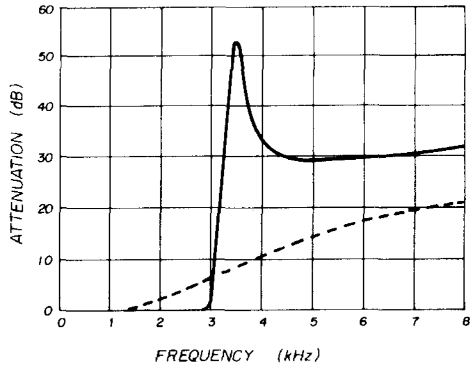

fig. 3. Measured attenuation characteristics of the lowpass filter shown in fig. 1 with a 2940-Hz cutoff frequency. The dashed line shows the measured attenuation characteristics of a comparison pi-section filter with the same nominal cutoff frequency and load resistance.

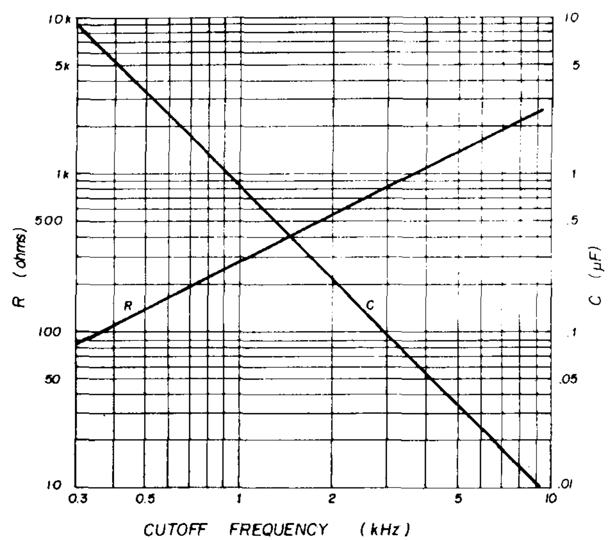

fig. 2. Values of R and C as functions of the cutoff frequency for the lowpass filter circuit shown in fig. 1 with L = 88 mH. For L = 44 mH, C should be doubled and R halved.

operating characteristics

The attenuation characteristics of the resultant filter were measured and are shown in **fig. 3.** Also shown (dashed curve) are the measured attenuation characteristics of a comparison pi-section filter having the same cutoff frequency and load resistance. The pi-section filter was made from an 88 mH toroid and two 0.067 μF capacitors. The superiority of the filter circuit of **fig. 1** is obvious.

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More Details? CHECK—OFF Page 110

More Details? CHECK—OFF Page 110

medium-power toroidal antenna tuner

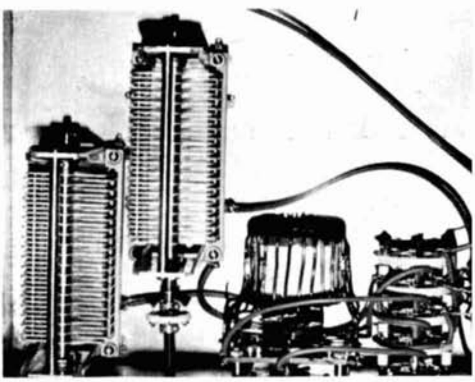
Design and construction of a compact antenna tuner that will handle up to 500 watts

Gregory Widin, WB2ZSH, Box 248, Gambier, Ohio 43022

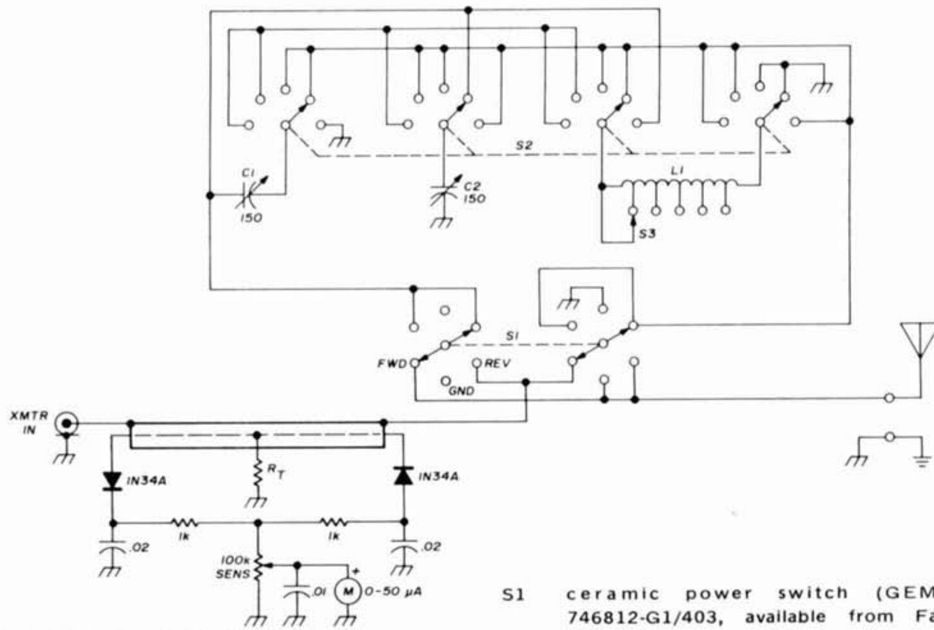
Though numerous designs have been presented for antenna tuners, most are anything but simple and convenient to use. Moreover, the tuners described for limited space applications are themselves often far from compact.

The antenna tuner described here overcomes these problems by attacking the primary culprit – the inductor. Designs using plug-in, rotary or clip-tapped inductors are superseded with the use of a switch-tapped toroidal coil, thereby substantially reducing space requirements and the inconvenience of bulky tap connections. The circuit is based on the recommendations of W2EEY,[1] and provides matching to random length wires. An indicator is included for "hands-free" tuning.

The coupler provides nine different circuits using two capacitors and one coil (see **fig. 2**). Configurations A through E are provided by switch S2, and the forward/reverse function is accomplished by switch S1. The different circuit arrangements provide for a variety of impedance-matching situations.



Closeup of the matching network components in the toroid antenna tuner. Variable capacitors C1 and C2 are to the left, toroid inductance L1 is to the right.



C1,C2 150-pF variable (Millen 12515)

L1 24 turns no. 12 Formvar wound on two Amidon T-200-2 cores, tapped at 4, 6, 8, 10 and 12 turns (see text)

R_T same resistance as load, 50 ohms for most amateur systems (see reference 2)

S1 ceramic power switch (GEML 746812-G1/403, available from Fair Radio)

S2 4-pole, 6-position, non-shorting rotary switch (CRL 2553)

S3 12-position tap switch (JBL Inst. 240 type BPBN-1-RA-83-3Z9825-40.2, available from Fair Radio)

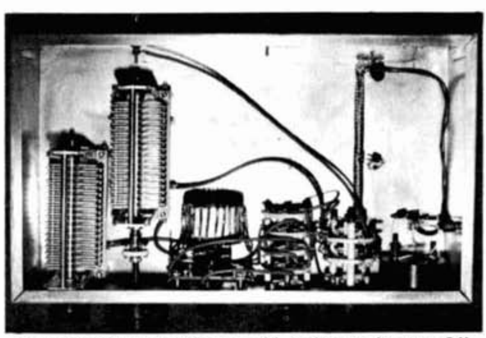
fig. 1. Schematic diagram of the toroid antenna tuner. This tuner will handle up to 500 watts CW without arcing, and is designed primarily for matching long-wire antennas from 80 through 10 meters.

construction

Building the toroidal antenna tuner is relatively straightforward. The toroid is the most unusual part of the circuit and consists of two Amidon T-200-2 toroidal cores epoxied together. The entire surface of each of the toroids is covered with epoxy to prevent flashover from the coil to the cores. Spacers of 1/4-inch polystyrene are then cut out as shown in **fig. 3** and glued to the ends of the dual toroid.

When the epoxy has cured, the wire may be wound on the toroids – 24 turns of number-12 Formvar-insulated wire are required. Care should be taken not to flex the wire more than necessary, as this will work harden the wire. Also, the neater the job, the less likely you will have arcing problems in the finished tuner. Leave enough wire at each end to secure the coil to the tap switch.

The tap leads from the coil are connected before the coil is wired to the



Construction of the toroid antenna tuner. All components are mounted in a small aluminum chassis.

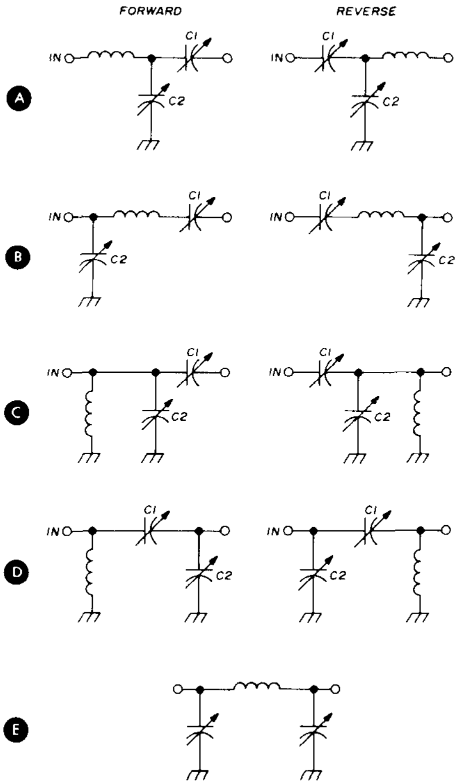


fig. 2. Different matching network arrangements possible with the antenna tuner shown in fig. 1.

switch. Beginning after the first 4 turns, taps are connected every 2 turns, for a total of 12 leads, including those at each end of the coil. To connect the taps, scrape away the insulation on the proper turn on the outside of the coil between the spacers. Another piece of number-12 wire with a clean end is then wrapped to this point with several turns of small gauge wire. Then the connection is soldered.

When the tap leads are all connected, the coil may be wired to the switch. The first contact is left blank, and the second contact connects to the first tap after the initial 4 turns on the coil. The wires are connected around, in turn, and support the coil. The wiper should be connected to the end of the coil with the 4-turn tap.

The capacitors were obtained, in new condition, from a surplus A-27 Phantom Antenna unit.* These units also supplied the ground and antenna binding posts, which are more rugged than most. Note that one capacitor must be fully insulated from ground.

Since the forward/reverse switch provides 3 positions, the center position is used to ground the antenna when the equipment is not in use. A dummy load might be connected to the input side in this position to provide a tune option.

The swr indicator shown in **fig. 1** is a modification of an earlier design.[2] I used a pickup braid 8-inches long to give significant indication in the transmitter tune-up position. The sensitivity control used was a subminiature type, but a front-panel adjustment would be more satisfactory. The indicator portion of the tuner should be shielded to prevent possible rfi effects.

The tuner could easily be built into a small enclosure. Front panel space is the main limitation on compactness. The finished unit is capable of handling 500 watts CW without arcing. Using a long-wire antenna of sufficient length, the tuner will easily match transmitter outputs from 80 through 10 meters.

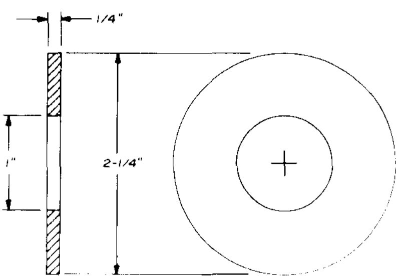


fig. 3. Polystyrene end spacers for the toroidal core (see text).

references

1. John J. Shultz, "Random-Length Antenna Couplers," *ham radio,* January, 1970, page 32.
2. Gregory P. Widin, "SWR Bridge," *ham radio,* October, 1971, page 55.
3. E. L. Klein, W4BRS, "The Whole of the Doughnut," *73*, June, 1967, page 6.

ham radio

*A-27 Phantom Antenna units, used, are priced at $2.95 plus shipping (3 pounds) from Fair Radio Sales Co., Post Box 1105, Lima, Ohio 45802.

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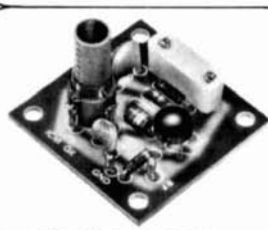

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four-band high-frequency windom antenna

The rebirth of the Windom antenna — a high performance multiband antenna popular in the 1930s

Hal Morris, W4VUO, 354 Krams Avenue, Philadelphia, Pennsylvania 19128

Do you have antenna space limitations? Can't swing a rotary beam? Need a good field-day antenna? Then the old standby, the Windom antenna, may be your answer. It offers four-band operation with a single feedline, and in most cases does not require an antenna tuner.

It's odd how ideas crop up in ham radio and then fade into oblivion. The Windom is a good, simple, multiband antenna system that is unheard of among today's hams. So, let's revive it and simplify the feed system. (This will be old hat to you if you remember when you weren't one of the boys on 75 meters unless you had an RME-45 receiver and a Windom antenna.)

theory of operation

If the impedances present along the length of a half-wave dipole in free space are plotted, the values vary from about 3600 ohms at the ends to 72 ohms at the center. **Fig. 1** is a plot of antenna impedance versus length along a dipole. The center impedance of 72 ohms, coupled with the ease of using coaxial cable, has given rise to the extensive use of low-impedance feedlines and single-band dipoles. Today, open-wire feeders and other than 50- or 72-ohm coaxial feedlines are rare.

However, one way of feeding a dipole with open wire-line is to tap the antenna equidistant from the center to match the feedline impedance. **Fig. 2** illustrates a method of matching 600-ohm line to a dipole. Note that the dipole does not have to be split into two parts with an insulator. This is called the delta match and is used extensively by vhf enthusiasts for matching stacked arrays.

preplanning

Lets calculate the length required for a four-band antenna. Since the highest frequency band, ten meters, will be the most sensitive to antenna length, overall antenna length must be some multiple of a half-wavelength at ten meters. From the handbook formula for long-wire antennas

$$\text{length in feet} = \frac{492\,(N - 0.05)}{\text{frequency (MHz)}}$$

where N is number of half waves.

For an antenna nine half-wavelengths long at 28.9 MHz, the length is slightly more than 152 feet. This is a bit long for 80-meter operation. Plugging in eight half waves and turning the crank gives

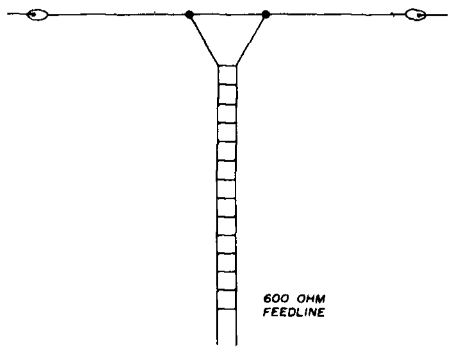


fig. 2. Classic single band antenna uses an open-wire feedline and a delta match. No center insulator is required.

135.342 feet. This looks good. Round the length off to 136 feet.

Now, using the formula for a half-wave dipole, and working backwards to find resonant frequency

$$f_{MHz} = \frac{492}{\text{length}} = \frac{492}{136} = 3.617\text{ MHz}$$

This looks good. The 80- and 75-meter bandedge mismatch will be a small percentage of antenna length.

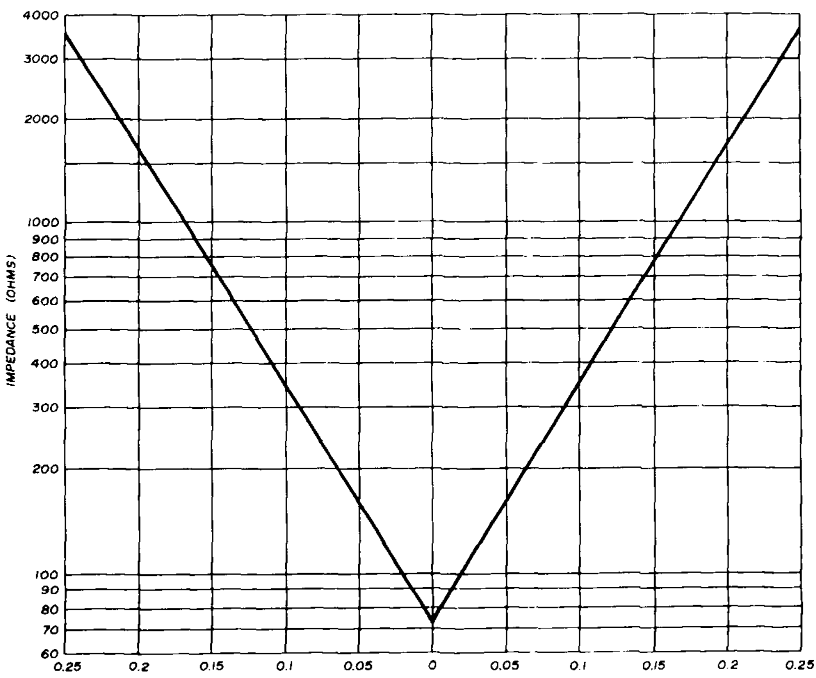


fig. 1. Plot of input impedance along a half-wave antenna in free space.

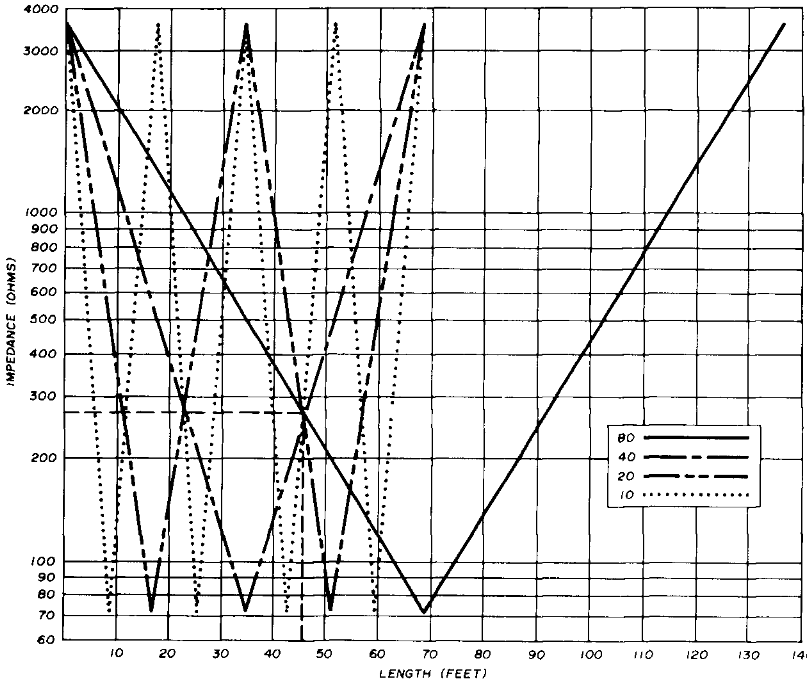


fig. 3. Impedance along a 136-foot antenna on 80, 40, 20 and 10 meters. Approximately 45 feet from one end of the antenna the impedance plots cross at 270 ohms — providing a fairly good match to 300-ohm feedline.

If the impedances present along this 136-foot antenna are plotted for the 80, 40, 20, and 10-meter bands, at a point 45 feet from one end, all four band plots cross at about 270 ohms (see **fig. 3**). If the antenna wire is broken at this point and the two wires are fed with 300-ohm twinlead, a fairly good match will be obtained for all four bands. In practice, certain lengths of feedline have been found to be preferred for easier transmitter loading. These lengths are multiples of 44 feet.

The advantages of both types of feedline, coax and twinlead, can be achieved by combining the optimum length of 44-feet of 300-ohm twinlead with a balun to match 75-ohm coax. A random length of coax can then be run to the hamshack as shown in **fig. 4**.

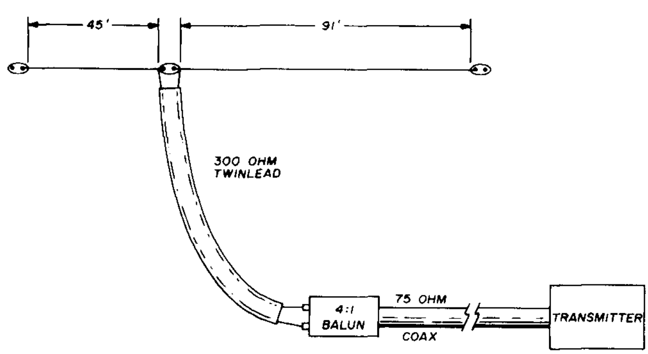


fig. 4. Windom antenna for four amateur bands uses 300-ohm twinlead, a 4:1 balun and 75-ohm coax to the transmitter.

construction

After obtaining 140-feet of number-12 Copperweld antenna wire, three egg insulators and 50-feet of 300-ohm twinlead, you are ready to proceed. Using the dimensions shown in **fig. 4,** install the three insulators. The distances shown are *between* insulators. Attach the premeasured 44-feet of 300-ohm twinlead (or multiples thereof) between the feedpoint insulator and the balun. Install the antenna as high and as in the clear as possible.

Route the 300-ohm feedline away from the feedpoint at a 90-degree angle for as far as possible. The balun should be waterproofed if it is exposed to the weather. One method is to completely wrap it with Scotch Brand vinyl tape of the type used by electricians and carried by most hardware stores.

There are several good commercial broadband baluns on the market that can be used, as well as toroidal kits for assembling a kilowatt unit in a small Minibox. The *ARRL Handbook* provides construction details for an easily made toroid balun.

There is one note of caution that applies to any multiband antenna system. Any harmonics generated on the lower bands will be efficiently radiated by this antenna. A conventional antenna tuner can be substituted for the balun, or used at the transmitter end of the coax to eliminate harmonics reaching the antenna. However, the use of an antenna tuner defeats the basic simplicity of the balun-to-coax feed system with its automatic bandchanging and no tuning to fuss with. Several excellent antenna tuners have been described in the amateur magazines.[1,2,3]

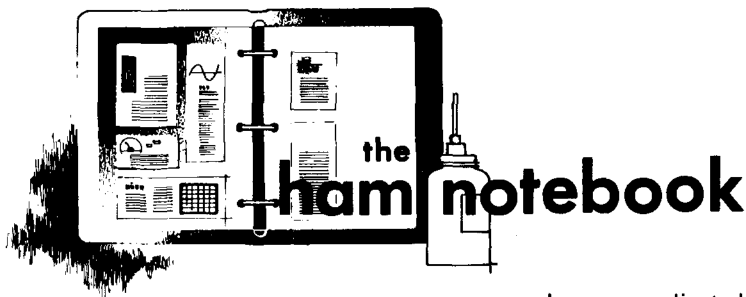
references

1. Ed Noll, W3FQJ, "Antenna Tuners," *ham radio,* December, 1972, page 58.

2. Gregory Widin, WB2ZSH, "Medium Power Toroidal Antenna Tuner," *ham radio*, January, 1974, page 58.

3. Ed Marriner, W6BLZ, "Match Box Antenna Tuner," *73,* September, 1966, page 38.

ham radio



spurious causes

While intruder-watching, and doing associated Official Observer work when an unusual signal turns out to be amateur rather than an intruder, much is learned about the causes of troubles.

Recently, there have been noted many cases of key chirps or clicks spaced many kilohertz from the normal signal. Sometimes it is noise, which may be keyed normally or back-keyed, or voice peaks in phase with the desired signal. Several hams have found tubes to be the cause, though plugging the offending tube back in the same socket may not again give trouble.

It has been suggested that this may be the result of generation of spurious frequencies due to a temporarily corroded tube pin or socket contact, which is self-cleaned by removing the tube and plugging it in again.

Therefore, it is suggested that all tubes in transmitters and receivers, particularly those associated with the generation of the transmitted signal, periodically be wiggled or even pulled out and plugged back in. It would seem that this could be done several times a year, to keep contacts clean, so that some screen or suppressor does not lose its voltage or its rf ground connection.

Bill Conklin, K6KA

line voltage monitor

It should be of interest to most hams to know the deviation from normal line voltage available at any time in their shack. Several line voltage monitors have been described, but these generally have been complicated by incorporating features that are not necessarily required. Self-calibration, for instance, requires a significant increase in the number of components as well as requiring high-cost, precision items.

The expanded scale-line voltage monitor I have built reduces the number of components significantly and does not compromise the accuracy to any great extent. As indicated by the schematic in

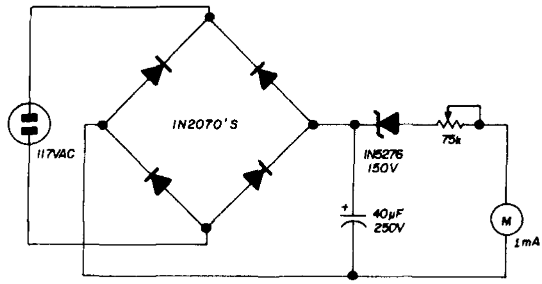


fig. 1. Simple expanded-scale line-voltage monitor reads from 115 to 125 volts on a 1-mA meter. Calibration is discussed in the text.

fig. 1, it consists of five active components, all of which were scrounged from my junk box.

However, for the recently licensed ham who may not have accumulated any sort of junk box, the cost of new parts, including the Minibox, cord terminal strips, etc., is under $7.50 (half of which goes for the milliammeter).

The whole circuit is mounted on terminal strips, so isolated from the chassis. Calibration was accomplished on a one-time basis using a Variac and a Simpson vom. With the Variac adjusted for 120 volts ac, the potentiometer was adjusted to give a mid-scale reading. The voltage was varied to 115 volts ac and 125 volts ac and the meter indication went to either end of the scale.

Intermediate points at 1-volt intervals were marked on the face of the meter for instant reference. Although a trace of non-linearity was detected on the high side the line-voltage monitor tracked remarkedly well to within a few percent.

Finally, if it is desired to obtain a larger variation (i.e., plus or minus 10 volts or some other value) a lower value zener, 140 volts or lower, may be substituted.

Alfred J. Parker, WA8VFK

two-meter power amplifier

TRW Semiconductors has announced the first in a series of reasonably priced, npn power transistors designed specifically for amateur radio equipment. The first transistor in the series, the PT5757, provides 10-watts output at 150 MHz with a 12.5-volt power supply and is designed for operation on the 2-meter amateur band. A single PT5757 will boost the 1-watt output of a 2-meter rig to 10 watts. A simple circuit is shown in **fig. 2.**

The PT5757 can also be amplitude modulated to approximately 60% without damage. Ideal for mobile operation, the PT5757 has better than 70% collector efficiency at 10 watts and 12.5 volts. For hand-held rigs at reduced power, excellent performance can be obtained with collector voltages as low as 8 volts. Best of all, the PT5757 is priced at $10.00 in single quantities, and is available from any TRW distributor or from Ham Radio Center, 8342 Olive Boulevard, St. Louis, Missouri 63132.

Jim Fisk, W1DTY

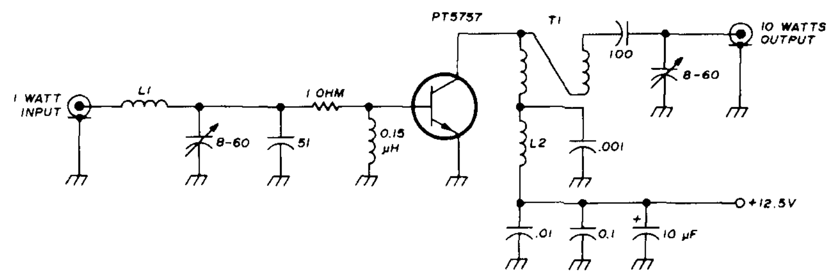


fig. 2. 10-watt 144-MHz power amplifier using the new TRW PT5757 transistor. L1 is 4 turns no. 20 enamelled, 3/32" ID; L2 is 10 turns, no. 20 enamelled, 3/32" ID. Transformer T1 is a 4:1 transmission-line transformer made from a 3" length of twisted pair, no. 20 enamelled wire.

ic lead former

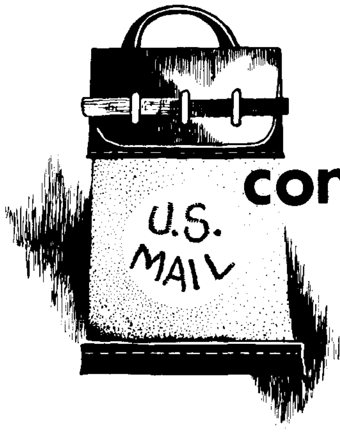
In making layouts for printed-circuit boards and in using breadboard circuits, difficulty has been encountered in connecting TO-5 can leads. Since the standard dual-inline-pack (DIP) configuration is very convenient for these applications, I decided to use this configuration for all ICs.

To accomplish the above, a lead former was constructed by drilling two rows of holes, 0.3 inch apart, with holes spaced on 0.1 inch centers in a piece of scrap printed circuit board stock. To use the lead former, the IC leads are inserted in appropriate holes, the IC pressed down, and the leads trimmed on the reverse side of the former.

In some applications, it is more convenient to use alternate holes (0.2 inch spacing) to provide additional spacing for an 8-lead IC such as the CA3028A. With this spacing, an 8-lead IC fits a standard 14-pin DIP socket. For further simplification, the unused leads of the IC may be clipped off near the can before connection.

This simple device provides a means of forming TO-5 can leads for the experimenter, simplifying his layouts.

Bill Stauffer, W5ICV



comments

receiver selectivity

Dear HR:

There have been articles over the years, and several recently, outlining the advantages and desirability of improving the front-end selectivity of the receiver. To see how a receiver of recent design checked in this respect, I checked out a Hammarlund HQ-215. This is a solid-state version of the Collins 75S receiver. Both have a 200-kHz bandpass i-f between the first and second mixers. The HQ-215 has three tuned circuits ahead of the first mixer – the 75S only two.

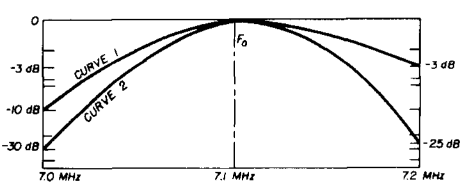


fig. 1. Passband characteristics of the HQ-215. See K4ZZV's letter for operating conditions for curves 1 and 2.

It can be seen from **fig. 1** (curve 1) that there is quite a wide passband to the incoming signals as far back as the second mixer input where the signal was recorded without agc. This was taken with the original rf swamping resistors removed to help the selectivity as much as possible!

Curve 2 was run with the i-f swamping resistors removed and everything peaked up for the band center. There are four tuned circuits in the HQ-215's first i-f. Nothing was changed in their intercoupling. Quite an improvement in the selectivity can be seen.

The noise figure of the receiver was halved with the additional gain so the first rf tuned circuit was stepped down enough to restore the original noise figure which would also improve the front-end overload characteristics. It looks like the next project should be a vari-cap network ganged to the vfo to make full use of the improved first i-f selectivity.

There are receivers that do tune the first i-f to their advantage. The Collins 75A4 is a good example. Getting as much selectivity as close to the antenna as possible really makes for the ultimate in reception. If one wants to confine their operation to a few Hz as the fixed-channel stations do, or guard a special traffic net frequency, a crystal filter at the antenna input is just the thing to clean things up. Maybe some day a variable frequency filter will be developed that will do what a few coupled LC circuits cannot.

There are trade-offs in receiver design though, and at least one solid-state receiver uses a tube in the front-end to handle the strong signals. It should make the old timers happy to know that tubes are still being used in modern design.

Wayne W. Cooper, K4ZZV
Miami Shores, Florida

code speed

Dear HR:

I certainly enjoyed VE2ZK's recent article on code speed, which mentioned that the FCC and ARRL use 50-bit words such as PARIS to establish the speed, and other government agencies use the 60-bit word CODEZ.

As a series of dots have equal "up-key" spaces between them, a string of dots is actually a number of dot cycles. Thus 25 dot cycles is the same as 50 continuous bits. This might clarify the author's mention of dividing by 25 to get the speed.

However, one of the most simple methods of determining speed without any mathematics is to merely send continuous number one (1) characters. Count the number sent in 24 seconds and this is the wpm for 50-bit rate. For 60-bit rate, count the 1's sent in 20 seconds. You could also use a digital counter with an automatic keyer although some counters might give erroneous results on the pulsed output of the keyer. Divide the counter reading by 25 to indicate wpm. It should at least get you in the ballpark, and many amateurs own digital counters these days.

The article was very interesting and it is the first time I can recall any author attempting to explain the 50- and 60-bit words and where they are used.

Irv Hoff, W6FFC
Los Altos Hills, California

attenuation pads

Dear HR:

I found the comments by Mike Goldstein, VE3GFN, on tuner overload memory in *ham notebook* of the January, 1973, issue, provoking. The problem I had was with converter overload when I was operating on 6 meters. Two other hams in my town who operated on 6 meters lived within half a block of me, so the old tubes of the converter would really light up when either of them came on.

I wanted to attenuate incoming signals *without changing* the impedance of my receiving system. A T-pad is just the device to do that. The Mallory RT-50, a 50-ohm pad, while designed for audio work, performed beautifully for me. As an experiment, I put it between my Heath Mohawk and the International Crystal converter and found that with the attenuation control set to zero, signals came in stronger on the Mohawk with the T-pad in the circuit than without it. I attribute this to better impedance matching created by inserting the T-pad between the converter and receiver. The pad would not only be helpful for converter overload due to strong signals, but also to receiver overload caused by too much converter output.

The Mallory RT-50 pad comes with knob, dial plate, mounting hardware and hook-up instructions, and can be obtained from many electronic stores and mail-order houses. If you have difficulty obtaining one, you can send $3.60 plus postage to Scott Electronic Supply Corporation, 4040 Adams Street, Lincoln, Nebraska 68504.

James Worrest, KØHNQ
Lincoln, Nebraska

sporadic-E openings

Dear HR:

The article on predicting sporadic-E openings by Morrie Goldman in your October, 1972, issue is quite informative. In fact, its usefulness extends beyond the author's original purpose. Several times in the past I have been plagued with spurious responses in my receiving equipment which were caused by the presence of nearby high-power paging transmitters. Your **table 1** will be quite useful in chasing down these problems in the future.

A second point which radio amateurs should find useful is the direct correspondence between **table 2** and our amateur call areas.

WØ, KØ	KA, KB	W5, K5	KK, KL
W1, K1	KC, KD	W6, K6	KM, KN
W2, K2	KE, KF	W7, K7	KO, KP
W3, K3	KG, KH	W8, K8	KQ, KR
W4, K4	KI, KJ	W9, K9	KS, KT

This correspondence makes it unnecessary to have to continually refer to the chart while monitoring a band opening.

Lewis D. Collins, K4GGI
Arlington, Massachusetts

new products

motorola vhf-fm radio for amateurs

Motorola, long a leader in two-way vhf-fm equipment, has now entered the amateur vhf-fm market through their subsidiary, Modar Electronics Inc., with the introduction of the new *Metrum II* two-meter vhf-fm radio. This radio, which covers the 144-148 MHz amateur band, is totally solid-state unit with a number of unique features. It is offered in 10- and 25-watt versions, both switchable to 1 watt.

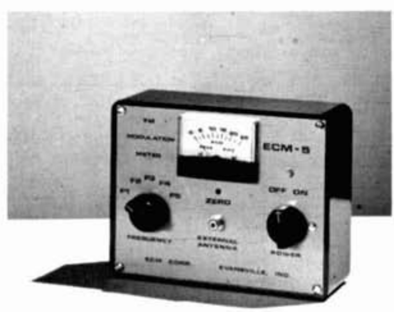
The modern, attractively styled line features a shadow bronze finish, 12-channel capability, the dependable Motorola microphone and field-proved circuitry. It incorporates a rotary on/off volume control, a variable squelch control, an illuminated control instrument panel, detent high-low power, detent repeater input and two detent auxiliary switches for custom adaption by the radio operators.

With built-in antenna mismatch protection, the *Metrum II* radio will continue functioning without damage to the unit even if the antenna is damaged, disconnected or improperly connected. Reverse polarity protection provides added safeguards against improper installation.

A specially designed reversible control panel allows the radio to be mounted in almost any position while maintaining clear visibility of all controls. A universal mounting tray permits installation at virtually any location. Indirect, non-glare back lighting of the *Metrum II* control panel means all controls can be read easily. Optional accessories include ac power supply, quarter-wave whip antenna, crystals, dimmer mod kit and rf indicator kit.

Manufacturer's suggested list prices for the 25-watt, 12-channel model and the 10-watt, 12-channel model version are set at $499.95 and $399.95, respectively. For further information on the *Metrum II* fm amateur radio, write to Modar Electronics, Inc., 2100 North Meacham Road, Schaumburg, Illinois 60172, or use *check-off* on page 110.

fm modulation meter



The ECM Corporation has announced the first commercially available fm modulation meter designed especially for the amateur. The ECM-5 covers all ham bands between 52 and 450 MHz, and features a peak reading meter. Deviation of any fm transmitter can be accurately adjusted between 5 kHz and 25 kHz in seconds, using voice or tone modulation.

The ECM-5 fm modulation meter closely follows the circuits used in professional equipment except that frequency is crystal controlled. This allowed ECM engineers to eliminate many expensive circuits needed only when frequency selection is vfo controlled. The net result was a tremendous reduction in price without sacrificing quality. The frequency selecting crystals are the popular, subminiature, third-overtone type used in many of today's fm receivers. These crystals were chosen for their low price and availability.

The peak reading meter has a special time-constant circuit that causes the needle to deflect upscale rapidly and downscale slowly. This allows the needle to follow voice peaks and increases the accuracy of readings when checking deviation using voice modulation. Other features include a builtin or external antenna, all solid-state construction, battery powered by inexpensive AA pencells, and a battery condition indicator.

The ECM-5 is priced at a low $75.00, less batteries and crystals. For more information, write ECM Corporation, 412 North Weinbach Avenue, Evansville, Indiana 47711, or use *check-off* on page 110.

multifrequency antennas

An antenna farm in your own backyard! That is what Don McVicar, VP7DX/VE2WW, has claimed to have developed in his new Mark IV, V and VIII multifrequency directional wire beams. Don has been experimenting many years with antennas and has developed an allband antenna system which is economical, mechanically sound, inconspicuous and easy to install. It gives good gains with a low angle of radiation at moderate installation heights.

Electrically, the Mark IV antenna has a minimum theoretical forward gain over a reference dipole of about 5.5 dB. While this is encouraging, consistent forward gains of up to 3 S-units have been achieved on both transmission and reception. Don assumes that these low-angle gains are due to the sloping inverted-vee configuration. On 40 and 80 meters the front-to-back and front-to-side ratios are from 9 to 20 dB and deep pattern nulls are not evident. On 20, 15 and 10 meters the front-to-back and front-to-side ratios vary between 12 and 30 dB. The feed-point impedance is 52 ohms, power capacity is 2-kW PEP and the antenna uses a single-line, all-band feed system.

Mechanically the system consists of two or more sloping inverted-vee antennas, one-half or 3½-wavelengths long, fed at their apex through a unique rf switch which causes the elements to react parasitically on one another. The switch is built for heavy-duty outdoor use. The antenna wire (not supplied) can be number-14 or equivalent, and the system tends to be self guying.

The rf switch may be installed on an existing rotator shaft beneath a Yagi or quad on any mast or tower such as an inexpensive 50-foot telescoping mast. For more information on this unique antenna system, write to World Wide Antennas, Box 467, Miami Springs, Florida 33166, or use *check-off* on page 110.

triggered-sweep 10 MHz oscilloscope

The new Eico Model TR-410 oscilloscope claims to be the industry's lowest priced lab quality, wideband triggered-sweep oscilloscope. It is expressly designed for speedy precision servicing, lab work, production testing and vocational instruction with such advanced features as automatic sweep which locks with complex tv signals, 10-MHz bandwidth,

More Details? CHECK—OFF Page 110

all solid-state design with protected fet input stage, and single dual probe to convert quickly from direct to 10:1 low capacitance operation. The instrument may be operated from a standard 120-volt line, low 100-volt or 220-230 volts — all 50/60 Hz. Included are three calibration voltages, 2, 5 and 10. The horizontal and vertical dc balance controls are adjustable with a screwdriver from the front panel for convenience and accuracy. Included are vertical and horizontal selection of ac or dc modes of amplification. The gate signal is available at a jack to enable the operator to synchronize other equipment to the trace displayed on scope. The astigmatism control is on the rear panel because once it has been set, readjustment is seldom, if ever, required. The removable sides, top and bottom provide easier and more accurate servicing and calibration. Standard bezel and bushings are provided for camera mounting.

The new Eico model TR-410 oscilloscope is priced at $379.95 and is available from your local Eico dealer. For more information, use *check-off* on page 110.

voltage-controlled attenuators

An economical series of three voltage controlled PIN diode attenuators cover the frequency range of 5-200 MHz for agc or leveling or other closed loop applications. Models VCA-1, 40 dB, 5-100 MHz; VCA-2, 30 dB, 5-100 MHz; VCA-3, 20 dB, 5-200 MHz; are offered. Maximum insertion loss is 6 dB. Vswr varies from 3.0 to less than 1.5:1, depending upon the attenuation setting. Rise and fall times of attenuation to specified values permit wideband modulation of rf signals. Units require up to 105 mA supply current and less than 5 mA control current. Positive or negative supply and control voltages may be specified. Connectors available include BNC, JCM (SMA compatible) and TNC. For more information, use *check-off* on page 110, or write to Radiation Devices Company, Post Box 8450, Baltimore, Maryland 21234.

low-noise 432-MHz preamps

As part of an expanding line of quality vhf/uhf products, Janel Labs has announced a series of 432-MHz preamps. Four models are available, offering low noise figures in a choice of two price ranges, each having the option of an ac power supply. Models without power supply (432PA and 432PC) have a compact sheet aluminum enclosure while those with power supply (indicated by the suffix −1) feature a rugged cast-aluminum case.

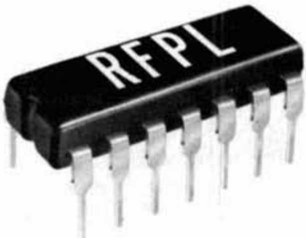
The gain of all models is an ample 20 dB. The 3-dB bandwidth is about 20 MHz. Stock units can be supplied for any center frequency between 420 and 470 MHz. Other frequencies are available on special order.

The basic circuit is a two-stage amplifier. This uses a KMC bipolar transistor first stage and a 3N159 dual-gate mosfet second stage. The 432PA uses a K2073 first stage to produce an outstandingly sensitive 3.5-dB noise figure. The 432PC uses the new K6007 to achieve an extremely sensitive 1.5- to 2.0-dB noise figure. The low cost 432PA and 432PA-1 are expected to see wide use for 450-MHz fm as well as for general purpose applications such as DX, ATV, and OSCAR.

The 432PC and 432PC-1 meet the needs of the most demanding applications such as moonbounce and weak-signal CW work. Prices range from $29.95 for 432PA to $94.95 for the 432PC-1. All are postpaid and guaranteed. For more information, write to Janel Laboratories, Box 112, Succasunna, New Jersey 07876, or use *check-off* on page 110.

 More Details? CHECK—OFF Page 110

rf directional couplers



RF Power Labs have introduced a new line of low-cost miniature wideband rf bidirectional couplers which should be very useful to amateurs who build their own high-frequency and vhf equipment. These versatile couplers can be used for power sampling for waveform monitoring and power level checkpoints, for load impedance and vswr measurements, and for direct readout of forward and reflected power over wide frequency ranges with excellent accuracy. Units are available in both dual-inline packages and *flat pak* configurations, and are capable of handling rf power levels up to 3 watts over their specified bandwidth.

Four models of the bi-directional coupler are available: the DC-14/14A, covering 2 to 300 MHz; the DC-14B/14C, covering 1 to 300 MHz; the DC-14D, covering 500 kHz to 100 MHz; and the DC-14E, covering 50 kHz to 100 MHz. Prices in small quantities range from $13.90 to $15.90 each. For more information, write to R.F. Power Labs, Inc., 92 - 104th Ave. N.E., Suite 103, Bellevue, Washington 98004, or use *check-off* on page 110.

digital catalog

ES Enterprises has announced the availability of a new 6-page catalog that describes their total line of digital products. Standard products include low cost programming instruments and controls, timers, clocks, counting and measuring devices. Also included is a complete listing of their modular display units for custom digital instrumentation and a section outlining their digital clock, multimeter and frequency counter kits.

The catalog contains descriptions of basic features, custom capability, standard options and warranty information. A price list and ordering instructions accompany the catalog. For a copy of the catalog, write to ES Enterprises, 10418 La Cienega Boulevard, Inglewood, California 90304, or use *check-off* on page 110.

general-coverage receiver

Up to ten crystal-tuned frequencies can be preselected for drift-free automatic tuning on the latest high-quality general-purpose communications receiver from the British firm of Eddystone. The Model 1001 receiver has the unusual feature of a rechargeable internal power supply, consisting of a nickel-cadmium cell, which serves as a temporary standby in case of main circuit failure. The set will also work off an external 12V dc battery supply.

Covering frequencies from 550 kHz to 30 MHz, the set incorporates automatic gain control, wide/narrow selectivity control, carrier-level meter and both coarse and fine tuning knobs.

Frequency calibrations for tuning are marked on a horizontal scale drum which splits the 550-kHz to 30-MHz range into five bands. The scale display is about 6-1/2" long; a secondary scale below the main calibration can be used in conjunction with a vernier dial to provide a useful logging facility. Dial illumination can be switched on and off.

Aimed at the serious radio amateur, short-wave listener and DXer, the Model 1001 is designed to the most stringent

More Details? CHECK–OFF Page 110

professional specifications, and incorporates a variety of solid-state devices including integrated circuits and field-effect transistors. It drives its own pair of miniature speakers, and has output facilities for headphones, external speaker and tape-recorder. Price of the Model 1001 is about $900 delivered, including duty and taxes. The North American distributor will welcome inquiries from U.S. customers and prospective dealers. Write to Conway Electronic Enterprises Ltd., (Mr. J.W. Cave, General Sales Manager) 88/90 Arrow Road, Weston, Ontario, Canada, or use *check-off* on page 110.

radio transmitter principles and projects

Amateur radio operators, communications technicians and transmitter experimenters will profit from this new and completely up-to-date book by Ed Noll, W3FQJ. Devoted entirely to the subject of radio transmitters, this book also is perfect for those studying for the various grades of amateur or commercial FCC license examinations.

The first three chapters contain information on electron devices — the fet, bipolar transistor and the vacuum tube. Different modes of modulation — CW, a-m, fm and ssb — are discussed in other sections. Chapter 4 describes hybrid transmitter circuits using tubes and transistors. Double-sideband and single-sideband generation and circuits are covered in Chapter 5. There is a chapter on linear amplifiers and mixers; another explains integrated circuits. The final three chapters cover vhf circuits, frequency modulation and transmitter testing.

Each chapter begins with basic principles and advances to more detailed information. The projects are based on the basic principles and are designed to further the reader's understanding through actual experience. They also provide the radio amateur with complete plans to build his own gear. 320 pages, $6.95 (softbound). Order from Comtec Books, Greenville, New Hampshire 03048.

More Details? CHECK–OFF Page 110

collector's items

March 1968 (first issue)
FEATURING: 5-band SSB exciter, IC-regulated power supply, Remotely-tuned 10-meter beam, Transistor curve tracer, Double-balanced mixers.

May 1969
FEATURING: Potpourri of integrated-circuit applications, FM repeater receiver performance, RTTY converter, IC noise blanker, The ionospheric e-layer.

August 1969
FEATURING: Homebrew Parabolic Reflector, Solid-state Q-5er, Frequency calibrator with mos IC's, New multiband quad antenna, Troubleshooting with a scope.

September 1969
FEATURING: FM techniques and practices, IC power supplies, 1296-MHz varactor tripler, Tunable bandpass filters, Amateur microwave standards.

October 1969
FEATURING: Hot Carrier Diodes, Low-cost linear IC's, Diversity antennas, solid-state 432-MHz exciter, Tropospheric-duct communications.

November 1969
FEATURING: Op Amps . . . theory, selection & application, WWV receiver, Multiband antenna, Electronic key, Six-meter collinear.

August 1970
FEATURING: High-performance filter/preamplifier for vhf-uhf receivers, 100 MHz digital frequency scaler, Tunable audio cw filter, Stable solid-state vfo, Cubical-quad antenna design.

October 1970
FEATURING: An swr meter for accurate rf power measurements, Direct-conversion receiver, IC voltage regulators, 432MHz converter, Introduction to thyristors.

June 1971
FEATURING: A practical approach to 432-MHz SSB, FM carrier-operated relay, Audio agc systems, Practical IC's, Low-noise 1296-MHz preamp.

June 1972
FEATURING: 5 Band solid-state communications receiver, FM repeater control, SSTV synch generator, microwave experimenting.

August 1972
FEATURING: Frequency synthesizer for Drake R-4, 2304 MHz preamp, audio filters, RTTY Monitor scope, mobile touch-tone.

September 1972
FEATURING: HF power amplifier pi-network design, HF log periodics, RTTY distortion, frequency scaler, repeater timers.

October 1972
FEATURING: 4 channel spectrum analyzer, HF frequency synthesizer, all-band dipole, 160 meter vertical, multi-function IC's.

December 1972
FEATURING: Satellite communications, UHF swr bridge, RTTY monitor, receiver, FM channel elements, helical mobile antenna.

January 1973
FEATURING: Matching networks, digital readout VFO, fm repeater recoder, six-meter preamp, tuneable phase locked loop.

February 1973
FEATURING: Communications receiver design, rf speech clipper, fm receiver scanner, Plessey SL600 integrated cricuits, solid-state noise blanker.

March 1973
FEATURING: Solid-state 80-meter transceiver, reciprocating-detector receiver, AFSK generator, electronic keyers, mobile touch-tone.

June 1973
FEATURING: Digital RTTY autostart, fm repeater installation, micropower receiver, broadband amplifiers, logic oscillators.

July 1973
FEATURING: SSTV test generator, carrier operated relay, VHF receiver, two-meter frequency synthesizer, antenna matching.

September 1973
FEATURING: 220 MHz fm power amplifier, i-f sweep generator, speech processor, frequency synthesizer, log-periodic antennas.

October 1973
FEATURING: Keyer with random access memory, AFSK keyer, touch-tone decoder, antenna matching, rf power meter, VHF pre-scaler.

November 1973
FEATURING: Low power transmitter for 20 meters, Motorola test set, RTTY tuning unit, ssb transceiver, DX antennas, repeater-site calculators.

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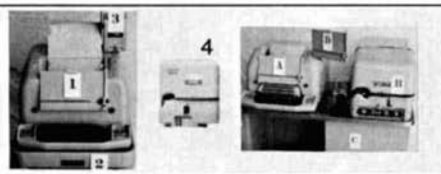

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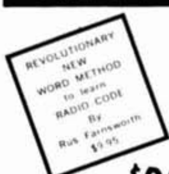

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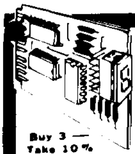

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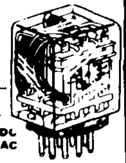

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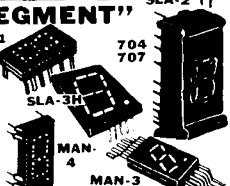

All fit 14-pin IC sockets. All 7-segments. MAN Series "all LED" and made by well-known West Coast mfgr. Others Reflective Bar type made by OPCOA and LITRONIX. The Reflective Bar types are low-cost versions of the MAN's except .33 character height! If one LED blows you lose a segment. MAN's you DO NOT! All readouts 0-to-9 numerals, plus letters and decimal. **Opcoa and Litronix products pin-for-pin replacements for MAN-1 MAN-4. All 5V TTL compatible.

ALL LED READOUTS — TYPE	character Size	Color Display	Decimal	Mils	Driver	Each	Special
☐ MAN-1 equal	.27	Red	Yes	20	SN7447	$4.50	3 for $12.
☐ MAN-1A equal*	.27	Red	Yes	20	SN7447	4.95	3 for $13.
☐ MAN-3 equal	.115	Red	Yes	10	SN7448	2.50	3 for $6.
☐ MAN-3A equal*	.115	Red	Yes	10	SN7448	2.50	3 for $6.
☐ MAN-3M equal*	.127	Red	Yes	10	SN7448	2.50	3 for $6.
☐ MAN-3 equal	.115	Red	***	10	SN7448	1.95	3 for $5.
☐ MAN-3M equal*	.127	Red	Yes***	10	SN7448	1.95	3 for $5.
☐ MAN-4 equal*	.190	Red	Yes	15	SN7448	3.25	3 for $9.
☐ MAN-4 equal*	.190	Red	Yes***	15	SN7448	2.75	3 for $8.
"REFLECTIVE LITE BAR" (Segment LED Readouts)							
☐ 707** (MAN-1)	.33	Red	Yes	20	SN7447	3.25	3 for $9.
☐ 704** (MAN-4)	.33	Red	Yes	20	SN7448	3.25	3 for $9.
☐ SLA-1** (MAN-1)	.33	Red	Yes	20	SN7447	3.25	3 for $9.
☐ SLA-2 + − 1	.33	Red	No	15	SN7447	3.25	3 for $9.
☐ SLA-3H Giant	.70	Red	Yes	20	SN7447	6.50	3 for $18.
☐ SLA-11C** (MAN-5	.33	Green	Yes	40	SN7447	5.95	3 for $15.
☐ SLA-12** ±1	.33	Green	No	40	SN7447	3.50	3 for $ 9.

* Red epoxy case, others clear. ** Litronix and Opcoa's pin-for-pin equals and electrical specs as MAN-1 or MAN-4. *** LED "dot" missing.

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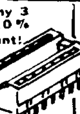

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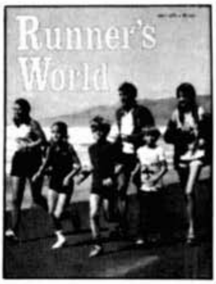

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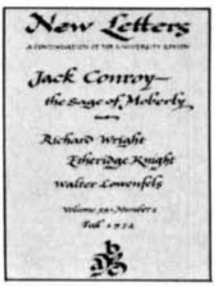

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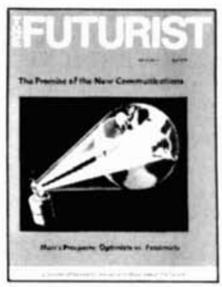

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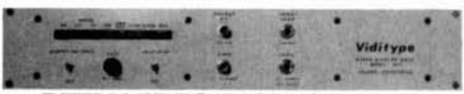

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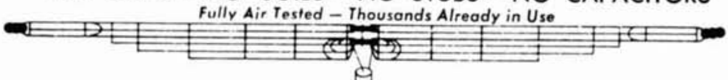

#16 40% Copper Weld wire annealed so it handles like soft Copper wire—Rated for better than full legal power AM/CW or SSB-Coaxial or Balanced 50 to 75 ohm feed line—VSWR under 1.5 to 1 at most heights—Stainless Steel hardware—Drop Proof Insulators—Terrific Performance—No coils or traps to break down or change under weather conditions—Completely Assembled ready to put up—Guaranteed 1 year—ONE DESIGN DOES IT ALL; 75-10HD—ONLY $12.00 A BAND!

Model 75-10HD	$60.00	66 Ft	75 Thru 10 Meters
Model 75-20HD	$50.00	66 Ft	75 Thru 20 Meters
Model 75-40HD	$40.00	66 Ft	75 Thru 40 Meters
Model 40-20HD	$33.00	35 Ft	40 Thru 20 Meters
Model 80-40HD	$42.00	69 Ft	80-40-15 Meter (CW)

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If you like 2 METER...

YOU'LL LOVE OUR

15 OR 1 WATT POWER OUT/SWITCH SELECTABLE/
FULL 12 CHANNEL TRANSMIT AND RECEIVE CAPABILITY

You'll like the crystal clear transmit and receive performance of this compact, 2 meter unit and so will those listening. The 12 transmit channels are provided with individual trimmer capacitors for the optimum in point-to-point and repeater applications. A HI/LO power switch provides 1 watt output or full rated output. The receiver has an audio output of 3 watts at excellent sensitivity. Solid state, American made quality at a low price.

$229.00 AMATEUR NET

includes plug-in ceramic mike, mounting bracket and transmit and receive crystals for 146.94 MHz.

Regency
the first name in solid state

THE FM LEADER IN 2 METER AND 6 METER... AND NOW 220 MHz

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flea market

RATES Commercial Ads 35¢ 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.

GOOD NEWS — SRRC Hamfest June 2, 1974 at fabulous new site in Princeton Illinois Fairgrounds. SRRC-W9MKS, R.F.D. #1, Box 171, Oglesby, Illinois 61348.

TONE-LOGIC Educational Systems for WWV, SSTV, RTTY. Eight 2¼" x 3" PCB's, plans, $3. Hornung, Box 24614, San Jose, CA. 95154.

FRAME & DISPLAY your QSL's with 20 pocket plastic holders. Two for $1.00, seven for $3.00 from your Dealer or direct, prepaid. Free sample to Dealers upon request. TEPABCO, Box 198H, Gallatin, Tennessee 37077.

FOR YOUR FUTURE ROBYN RADIOS send your order to, Two Way Radio Sales, 1501 Monroe Street, Bogalusa, La. 70427 or 202 Farrell Street, Picayune, Miss. 39466.

CALCULATOR OWNERS: Use your +—×÷ calculator to compute Square Roots, Trigonometric Functions, Logarithms, Exponentials and More! Quickly, Accurately, Easily! Send Today for the Improved and Expanded Edition of the First and Best Calculator Manual — now in use throughout the World . . . only $2.00 Postpaid! Be sure to try this manual before buying a more expensive calculator — Absolutely Unconditional Money-Back Guarantee — and FAST Service! Mallmann Optics and Electronics, Dept.-F, 836 South 113, West Allis, Wisconsin 53214.

QSLs CATALOG SAMPLES 35¢. Ritz Print Shop, 5810 Detroit Avenue, Cleveland, Ohio 44102.

HEATHKIT SB-102, CW filter, AC and DC supplies, mobile mount, remote LMO, speaker, manual, asking $475. Heathkit SB-110, AC supply, speaker, manual, $225. Also Hallicrafters HA-1 keyer, $50. All good condition. John Boston WB4RUA, Box 354, Calhoun, Georgia 30701. (404) 629-3048.

MOBILE IGNITION SHIELDING *provides more* range with no noise. Available most engines in assembled or kit forms, plus many other suppression accessories. Free literature. Estes Engineering, 543-H West 184th, Gardena, California 90248.

SIX ONLY PT4164C, TRW 25W RF transistor, same as 2N5591/SS4153. $6 each, all for $30. Bill Latta, 7309 Greenlawn, Louisville, Ky. 40222.

TREASURE COAST HAMFEST, March 9-10 — sponsors, Vero Beach Amateur Radio Club, Inc. and St. Lucie Repeater Association, Community Center, Vero Beach, Fla. 32960. Free continental breakfast — first prize 80-10 transceiver. Dozens of others. Speaker. Swappers row. Tickets and information, write: Ike Roach, K4QM, Box 3088, Vero Beach, Fla. 32960.

THE WEST ALLIS MIDWINTER SWAPFEST is Sunday, January 27, 1974 at Waukesha County Exposition Center located on Waukesha County Trunk Highway FT, southwest of the Waukesha County Airport. Directions: Take Waukesha County Trunk Highway F exit on I-94 south 1.2 miles to County FT and west .8 miles to swapfest. Doors open at 8 A.M. Refreshments available. Talk in station on 3985 and 146.94. Rain or shine. Tickets $1 advance; $1.50 at the door. For details write WA9KRF, 4582 South Ahmedi Avenue, Milwaukee, Wisconsin 53207.

SIGNAL ONE OWNERS, expert and prompt service by ex-Signal/One engineer. Also will purchase your functioning or not functioning unit or spare parts. Write or call for details. Larry Pace, K2IXP/7, 1071 W. Roller Coaster, Tucson, AZ. 85704 (602-888-5234).

CIRCULATORS 1.65 - 2.1 gig $21.00 pp. Joe McCormick of Lake City has been using on 2.3 in tropo with v.g. results. Some 2.0 - 2.4 gig $35.00 pp. Most have sn sheets, charts. Eimac IK20XN-A, new $16.00 pp. TWS 12 or TWS15 TWT G.E., 1.7 - 2.7 gig 30 mw in 20 watt out, most with sn sheet. New $165.00 REA only. Eimac WL200, mixers, isolators, wave meters, most x band. Ramcor M & L 1200B Densiometer sn L band & ant. book and chart, $55.00 pp. If you have my last list take 20% on any piece of equipment, or clean me out. Doug Craton, 5625 Balfrey Dr., W. Palm Bch, Fla. 33406.

P.C.'s Need a project for winter? Send a SASE for list of available boards. Semtronics, Charles R. Sempirek, Route #3, Box 1, Bellaire, Ohio 43906.

432 MHz TRANSMITTER CONVERTER, 5 watts out, 6939 mixer, 6939 amplifier and solid state LO chain. 4½ x 7½ cast aluminum box. Send for more information. Carmichael Communications, P. O. Box 256, Carmichael, CA 95608.

MANUALS for most ham gear made 45/65, some earlier. Send SASE for specific quote. Hobby Industry, WØJJK, Box H-864, Council Bluffs, Iowa 51501.

TOUCH-TONE PADS . . . twelve button . . . lighted $15.00 . . . unlighted $11.00 . . . postpaid/Insured . . . Swank Roberts, WA5GNT, 1130 Fuller Drive, Apartment 223, Dallas, Texas 75218 . . . (214) 328-9307.

PRINTED CIRCUIT DRILL BITS. Trumbull, 833 Balra Drive, El Cerrito, California 94530.

FOR SALE: 30S-1; 51S-1; 55G-1; 312B-4; 32S-3; 516F-2; Hallicrafter keyer: Vibroplex key. Package: $2,875. You pay shipping — Certified check or money order. All in excellent physical and functional order. No time to use. K8ACF - 15317 W. Brant Road, St. Charles, Michigan 48655. Phone (517) 585-2966 - nights or weekends (517) 636-9333 - days.

EMBROIDERED EMBLEMS AND PATCHES. Custom made from your design. 10 to 1000's. Write Russell, 1109 Turner St., Augusta, Maine 04210.

WORLD QSL — See ad page 86.

10 POUNDS ELECTRONICS PARTS $10, Tubes for *sale too . . . Williams, P. O. 7057, Norfolk,* Va. 23509.

HIGH-PERFORMANCE H.F. SYNTHESIZER replaces VFO and delivers output 1-30 MHz continuous coverage with accuracy, stability, resolution, and calibration to one Hertz. Write for information. Petit Logic Systems, Box 51, Oak Harbor, Wa. 98277

SEND PERFECT MORSE WITH YOUR RTTY and save over $150 on price of a comparable Morse keyboard. TMC-1 RTTY to Morse converter connects right into your loop trouble-free and accepts input from keyboard or paper tape reader. Entire circuit including 64-letter buffer memory on one 4 x 6 inch board for $310. Write for information. Petit Logic Systems, Box 51, Oak Harbor, Wa. 98277

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1000 PIV AT 2.5 AMP DIODES. New Motorola HEP-170. 10 for $2.50, 100 and up 20¢ each, postpaid. K. E. Electronics, Box 1279, Tustin, California 92680.

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

LAKE COUNTY IND. Amateur Radio Club Banquet. For the 21st consecutive year, the Lake County Amateur Radio Club, Inc., proudly announces its annual banquet. The date is February 9, 1974, and the time is 6:30 p.m., CST (We start on time). The place is the Sherwood Club, 600 E. Joliet St., Schererville, Ind. (Two miles east of Rt. 41, ¼ mile north of Rt. 30). Chicken dinner — all you can eat — awards, fellowship, speeches, entertainment, gifts, all for $6.00 per ticket. Come. Bring your wife or girl friend. Tickets available from club ticket volunteers or from the ticket chairman, Herbert S. Brier, W9EGQ, 385 Johnson St., Gary, Indiana 46402. Positively no tickets sold at the door!

RTTY BAUDOT LOOP TO ASCII CONVERTER accepts loop signal at any RTTY speed and delivers corresponding 6 or 8 level parallel ASCII, all on one 4 x 6 inch circuit board for $120. Petit Logic Systems, Box 51, Oak Harbor, Wa. 98277

TELETYPEWRITERS — Kleinschmidt — portable, fixed, sets, punches, parts, reconditioned, reasonable. Mark/Space Systems, 3563 Conquista, Long Beach, Calif. 90808. 213-429-5821.

ACTIVE HAMS — Monthly mailer of reconditioned and new equipment specials. Sell · Buy · Trade. Write: Associated Radio, 8012 Conser, Overland Park, Kansas 66204

TRAVEL-PAK QSL KIT Converts photos, post cards to QSLs! Send call and 25¢ for personal sample. Samco, Box 203H, Wynantskill, N. Y. 12198.

WE BUY Late Model Collins-Drake-Swan. Top prices cash. Associated Radio, 8012 Conser, Overland Park, Kansas 66204. Call: 913-381-5901.

FOR SALE: Commercial Test Equipment. Send SASE for equipment list. Northern Communications & Equipment, Inc., P. O. Box 1000, Auke Bay, Alaska 99821.

TECH MANUALS for Govt. surplus gear — $6.50 each. R-220/URR, R-389/URR, R-390/URR, R-274/FRR, SP-600JX, BC-639A, BC-779B, USM-16, URM-32, TS-497B/URR, OS-8C/U, TT-63A/FGC, CV-591A/URR, BC-160, GRC-19, TS-403/U, URM-25D, RCK, LM-21, TS-148/UP, BC-348JNQ, TS-382D/U, PRC-10, ALR-5. Thousands more available. Send 50¢ (coin) for list. W3IHD, 7218 Roanne Drive, Washington, D. C. 20021.

SILVER PLATING BREAKTHRU! No mess or lethal chemicals. Simply brush on. 6 liquid ounces plates 1800 square inches copper · brass. Durable. $6.50. Abar Research, 11118 Parker, Mokena, Ill. 60448.

HAM ASTRONOMERS: Complete standard Questar, 3½ inch, full aperture sun filter, Exacta 35mm. SLR camera, adaptors, Linhof tripod, etc. WA8YNI, 1720 N. Broadway, Hastings, MI 49058.

WE BUY ELECTRON TUBES, *diodes, transistors,* integrated circuits, Semiconductors. Astral Electronics, 150 Miller Street, Elizabeth, New Jersey 07207, (201) 354-2420.

SELL: IRE Proceedings Unbound 1928 thru 1972. 45 volumes · best offer. Gonset G50 6m XCVR $110. WA2DWV, R. D. 1, Box 155, Freehold, N. J. 07728.

USED MYLAR TAPES — 1800 foot. Ten for $8.50 postpaid. Fremerman, 4041 Central, Kansas City, Mo. 64111.

VERY in-ter-est-ing! Next 5 big issues $1. "The Ham Trader," Sycamore IL 60178

DAYTON HAMVENTION expands to three days April 26, 27, 28, 1974 at HARA Arena and Exhibition Center. Brochures mailed March 15th. Write for information if you have not attended the last two years. P. O. Box 44, Dayton, Ohio 45401.

MOBILE OPS — Completely shielded ignition system kits available for most U.S. cars 1965-73. Alternator, generator and regulator filters, feed-thru capacitors, copper braid in stock. Write Summit Enterprises, 36 Winchip Road, Summit, N. J. 07901.

TEXTRONIX 535A OSCILLOSCOPE: Dual trace, triggered sweep. Less probes, laboratory calibrated, $575 or best offer. You pay shipment. H. Karimi, Box 405, Fairborn, Ohio 45324.

L. I. Electronic Supermart
(Off the wall self service)

New P.C. Boards — G10, 1 oz. · 1 side copper-fiber glass
6" x 6", 80¢ ea. — 6 x 12, $1.50 ea. · 12 x 12, $2.85 ea.
New P.C. Boards — G10, 1 oz. · 2 side copper-fiber glass
6" x 6", $1.10 ea. · 6 x 12, $2.00 ea. · 12 x 12, $3.75 ea.
New P.C. Boards — G10, Fiber glass punch:
F Pattern 4.5 x 6.5, .062 holes, 5 per 1" $1.30
P Pattern 4.5 x 6.5, .042 holes, 10 per 1" $1.35
G Pattern, 4.5 x 6.5, .062 holes, $1.30
Pkg. 10 Bircher P.C. Board, metal 2" slides $1.00
Package of 50 flea clips for above punched Boards, .062 ..... 75¢
30 ¼ or ½ W resistors, packaged 5 per value your choice of values $1.00
25-1W resistors, packaged 5 per value, your choice of values $1.00
15-2W resistors, packaged 5 per value, your choice of values $1.00
5 ¼ or ½ W, 1% resistors, packaged 5 per value, your choice of values ..... .50
5 ceramic disk caps, .001-01, packaged 5 per value, your choice of values ..... .50
5 mica dip caps, 1 pf-150 pf, packaged 5 per value, your choice of values ..... .50
5 mica dip caps, 180 pf-820 pf, packaged 5 per value, your choice of values ..... .75
5 mica dip caps, 910 pf-1500 pf, packaged 5 per value, your choice of values $1.00
Wire Kit #22 solid PVC, 6 spools, 6 colors, 50' ea. spool $3.50
Wire Kit # 22 stranded PVC, 6 spools, 6 colors, 50' ea. spool $3.50
Wire Kit #24 Solid PVC, 6 spools, 6 colors, 50' ea. spool $3.50
Wire Kit #24 stranded PVC, 6 spools, 6 colors, 50' ea. spool $3.50
10' — Ten cond. ribbon wire, color coded, #22 or #24, stranded $1.50
C & K #7101 mini switch, SPDT on-on $1.05
C & K #7103 mini switch, SPDT on-off-on $1.20
C & K #7201 mini switch, DPDT on-on $1.35
C & K #7203 mini switch, DPDT on-off-on $1.55
Alco 105D MST momentary on-off-momentary on $1.25
Central Lab DPDT push momentary. SPEC. 4/$1.00
Connectors, PL259, $.45; PL258, $.70; 175U or 176U, $.20 ea.; UG 88 cu., $.50; UG 201 a/u (N to BNC adapter), $.75; RCA to UHF, $.90.
Encapsulated chokes 1uh to 5 Mh, choice 3/$1.00
Varo type mini bridge rectifiers, approx. ⅝" sq. size: 2 amp. · 50 v., $1.25; 4 amp. · 50 v., $1.25; 6 amp. · 50 v., $1.25; 2 amp. · 100 v., $1.25; 4 amp. · 100 v., $1.25; 6 amp. · 100 v., $1.25; 2 amp. · 200 v., $1.50; 4 amp. · 200 v., $1.50; 6 amp. · 200 v., $1.50; 2 amp. · 400 v., $1.50; 4 amp. · 400 v., $1.50; 6 amp. · 400 v., $1.50
Triacs — thermo tab package — 1 amp. · 400 v., $.80 ea.; 3 amp. · 400 v., $1.40 ea.; 4 amp. · 200 v., $1.20 ea.; 6 amp. · 200 v., $1.40 ea.; 6 amp. · 400 v., $1.60 ea.; 6 amp. · 500 v., $1.80 ea.; 8 amp. · 200 v., $1.60 ea.; 8 amp. · 500 v., $1.80 ea.
To-5 case, 1 amp. · 200 v., $.70 ea.; 1 amp. · 400 v., $1.00 ea.
SCR 200 v. · 8 amp. thermo tab ..... $.80 ea.

SEND SELF ADDRESSED ENVELOPE FOR FREE MAILER. INCLUDES MANY HUNDREDS OF ITEMS NOT LISTED ABOVE.

Send check or money order · include 60¢ to cover parcel post and handling. UPS shipping available. Minimum order $4.50.

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"DON AND BOB" DISCOUNT PRICES Plus Full Warranty. Call or write fast quotes. All items new, guaranteed. SBE144 199.95; Midland 13500 2MFM 15W mobile 219.95; 13509 W-T 2W. 209.95; SBE-450TRC, converts 2M-3/4M 149.00; 20%-plus off list: Hy-Gain TH6DXX 143.00; Mosley Classic 33 124.00; Ham-M 59.00; TR44 59.95; Belden 8-wire rotor cable 8448 10¢/ft; 8214 RG8 foam coax 17¢/ft; Hy-Gain 400 rotor (230.00L) 179.00; 5COND. rotor cable 19¢/ft; 15% off list Triex, Rohn tower; 3/16" cable clamps 18¢ ea; #15 antenna wire 1.95/C; Motorola HEP170 epoxy diode 2.5A/1000 PIV 29¢, 25.00/100 lot; .001MFD/10KV doorknob (CDE) 1.95; Hammarlund HF50 1.95; Motorola semi-conductor data series 7.50; Sorensen ACR-2000VA AC regulator 150.00; write quote Swan, Eimac, Drake, Kenwood Ten-Tec; Calrad KW SWR-relative power dualmeter bridge, to 150MHz 15.95; all items guaranteed. Free flyer, Prices FOB Houston, include postage with small orders, excess refunded. Madison Electronics, 1508 McKinney, Houston, Texas 77002. 713/224-2668, nite/weekend 713/497-5683.

SELL: Every issue of '73 Magazine. All offers considered. John Hill, W4WXJ, 2885 Lyncrest Drive, Nashville, Tn. 37214, 615-883-2163.

FIGHT TVI with the RSO Low Pass Filter. For brochure write: Taylor Communications Manufacturing Company, Box 126, Agincourt, Ontario, Canada. MIS 3B4

HOMEBREWERS: Stamp brings list of high quality components. CPO Surplus, Box 189, Braintree, Mass. 02184.

SELL: G. E. 2 meter progress line desk top base. 60 watts, with preamp, 2 frequency, 3 pair of crystals. Very clean. Best offer over $75.00. Also TR22, good condition, $150. Paul S. Smith, WB9JSE, 7723 W. Bender Ave., Milwaukee, Wis. 53218.

FREE with the purchase of a new Genave GTX-200 at $259.95: 18 crystals of your choice. Send cashier's check or money order for same-day shipment. For equally good deals on Drake, Standard, Clegg, Regency, Hallicrafters, Tempo, Kenwood, Midland, Ten-Tec, Galaxy, Hy-Gain, CushCraft, Mosley, Sony, and Hustler, write to Hoosier Electronics, your ham headquarters in the heart of the Midwest. Become one of our many happy and satisfied customers. Write or call today for our low quote and try our individual, personal service. Hoosier Electronics, Inc., R. R. 25, Box 403, Terre Haute, Indiana 47802. (812)-894-2397.

RESISTORS: Carbon composition brand new. All standard values stocked. ½W 10% 40/$1.00; ¼W 10% 30/$1.00 — 10 resistors per value, please. Minimum order $5.00. 15W RMS IC Audio Amplifier — Panasonic. Frequency response 20Hz-100 kHz. ½% distortion. Price $6.95 Postpaid. Pace Electronic Products, Box 161-H, Ontario Center, New York 14520.

QRP TRANSMATCH, Vari Q filter, FM crystal logic oscillator kits, Write Peter Meacham Associates, 19 Loretta Road, Waltham, Mass. 02154.

RECIPROCATING DETECTOR, write Peter Meacham Associates, 19 Loretta Road, Waltham, Mass. 02154.

ANEMOMETER — make your own wind guage — D.C. motor generator and instructions $3.00 postpaid. W2GKF, 55 Runnymeade Rd., Berkeley Heights, New Jersey 07922.

SPARE PARTS, tubes, xfmers, SSB-CW equip., and assy. SASE brings list. P. O. Box 437, North Hollywood 91603.

TEFLON WIRE #22 guage stranded, silver plated. $1.75/100 ft. Rich Shyer, 625-4 S. Palomares, Pomona, Ca. 91766.

SWAN 500C, 117X, 14C, $425. Triplett Model 221-T, 0-1000VDC, 0-1000ma, Model 420, 0-500VDC, 0-300 ma. $15 ea. Ballentine 303 $400. P. O. Box 1645, Grand Junction, Colo. 81501.

THE WHEATON COMMUNITY RADIO AMATEURS (WCRA) will hold their 12th Annual Mid-Winter Swap and Shop on Sunday, February 10, at the DuPage County Fairgrounds, Wheaton. Hours 8 a.m. to 5 p.m. Tickets $1.50 advance; $2.00 at the door. Two buildings again this year and unlimited parking. Bring your own tables. Free coffee and donuts 8:00 to 9:30 a.m. For info and advance tickets contact L. O. Shaw, W9OKI, 433 S. Villa Ave., Villa Park, Ill. 60181. Advance ticket orders must be postmarked no later than February 3, 1974.

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"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 Galaxy GT-550A Transceiver with supply and microphone, package $599.00: New Drake TR-22, reg. $219.95, cash $175.00: New Swan 270B, $375.00: New Collins in stock: New Rohn 50 ft. heavy-duty foldover tower, prepaid $255.00: New Mosley CL-33 and demo Ham-M rotor, $215.00: Used equipment: R4-C, $399.00: T4-XC, $425.00: R4-B, $309.00: Ham-M, $85.00: Nice KWM-2, $549.00: FPM-300, $489.00: Used TR-4C, $449.00. Moory Electronics Company, P. O. Box 506, DeWitt, Arkansas 72042. Tel: 501-946-2820.

QSL'S — BROWNIE W3CJI — 3111B Lehigh, Allentown, Pa. 18103. Samples 10¢. Cut catalogue 25¢.

SURPLUS TEST EQUIPMENT, VHF and microwave gear; write for bulletins. David Edsall, 2843 St. Paul, Baltimore, Md. 21218.

5939's, 6360's, Guaranteed good, $2.50 each. Jack W6TNR, 15718 Mayall, Sepulveda, Calif. 91340.

STOLEN EQUIPMENT — Standard Model SRC-146A FM transceiver in leather case, serial 208070, was stolen from aircraft at Los Angeles International Airport on October 5, 1973. Contact: Lt. W. L. Robinson, SLPD, Chief Security, Salt Lake City International. Phone (801) 328-7652 or P. O. AMF Box 22084, Salt Lake City, Utah 84122.

DO-IT-URSELF DXPEDITION — Stay at ZF1SB — Cayman Is. Vertical antenna and Caribbean at your doorstep. Diving/fishing if band folds. We arrange license. Write Spanish Bay Reef Resort, Box 800K, Grand Cayman, B. W. I.

DIGITAL frequency display for your receiver and transmitter. Detailed plans $3.00. Communications Electronics Specialties, 814 Orwell Ave., Orlando, Fla. 32809.

TELETYPEWRITER PARTS, gears, manuals, supplies, tape, toroids. SASE list. Typetronics, Box 8873, Ft. Lauderdale, Fl. 33310. Buy parts, late machines.

KLM AND MADISON ELECTRONICS present the best in VHF-UHF antennas. 143.5-148.5 MHz 7EL 21.95 up to 16EL. 49.95 — Write specifications. 220MHz; 432MHz 27EL. 41.95; write for quotes, prices FOB Calif. or Houston. Madison Electronics, 1508 Mc Kinney, Houston, Texas 77002. 713/224-2668, nite/weekend 713/497-5683.

PRECISION HAND TOOLS, special ham-experimenter discount. Letter brings mailings. Artisan Tool Company, Box 36, Glenmont, New York 12077.

WANT OLD RADIO SHOW TRANSCRIPTION discs. Any size or speed. Send details to, Larry Kiner, W7FIZ, 7554 132nd Ave. N.E., Kirkland, Wa. 98033.

CANADIAN JUMBO SURPLUS and Parts Catalogs. Bargains Galore. Send $1. ETCO-HR, Box 741, Montreal "A" H3c 2V2.

WANTED: tubes, transistors, equipment, what have you? Bernard Goldstein, W2MNP, Box 257, Canal Station, New York, N. Y. 10013.

REMOTE CONTROLS for mobile installations. I have several brand new Hartman remotes, complete with 18 ft. cable, Shure mic., mtg. bracket. All units are boxed and never used. $24.95 including postage to M. Cohen, 45 Pennington Way,, Spring Valley, N. Y. 10977.

NEED PARTS? We carry parts for R-388-390-390A-391-392-1051-51S1 - Nems Clark-Racal-Pack sets - PRC-25-41-47-62-70-71-73-74-77. If you need a part no matter what you have. If its U.S. government we have it or can get it.Also we want to buy or trade all aircraft communications. All ground radio communications. All plug-in modules control heads. No matter what cond. they are in - bent or busted ok. We will buy or trade. We have R-390-388-390A-392-1051-51S1 Nems Clark - Racal - and new ham gear for trade. D & R Electronics, R. D. #1, Box 56, Milton, Pa. 17847. Phone 1-717-742-4604 after 6:00 P.M.

STANDARD 146-A still in factory carton with warranty card. $238.70. W4OAQ, Box 17222, Nashville, Tenn. 37217, (615-834-8999).

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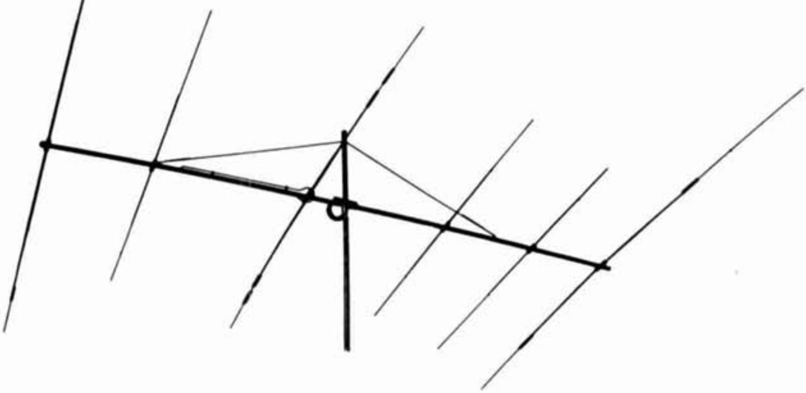
The voice of

HY-GAIN'S
THUNDERBIRD
10-15-20

is heard around the world



Here's why Thunderbirds outperform all other tri-banders:

- **Thunderbird's "Hy-Q" traps** provide separate traps for each band. "Hy-Q" traps are electronically tuned at the factory to perform better at any frequency in the band – either phone or CW. **And** you can tune the antenna, using charts supplied in the manual, to **substantially** outperform any other antennas made.
- **Thunderbird's superior construction** includes a new, cast aluminum, tilt-head universal boom-to-mast bracket that accommodates masts from 1¼" x 2½". Allows easy tilting for installation, maintenance and tuning and provides mast feed-thru for beam stacking.

  Taper swaged, slotted tubing on all elements allows easy adjustment and readjustment. Taper swaged to permit larger diameter tubing where it counts! And less wind loading. Full circumference compression clamps are mechanically and electrically superior to self-tapping metal screws.
- **Thunderbird's exclusive Beta Match** achieves balanced input, optimum matching on all 3 bands and provides DC ground to eliminate precipitation static.
- 25 db front-to-back ratio.
- SWR less than 1.5 to 1 on all bands.
- 24-foot boom... none longer in the industry.
- Extra heavy gauge, machine formed, element to boom brackets, with plastic sleeves used only for insulation. Bracket design allows full mechanical support.
- Interlaced, optimum spaced elements for higher gain and better pattern control.
- 3 active elements on 20 and 15 meters. 4 active elements on 10 meters.

New 6-Element Super Thunderbird
Model 389
Suggested retail price, **$189.95**

Improved 3-Element Thunderbird
Model 388
Suggested retail price, **$154.95**

Fabulous 3-Element Thunderbird, Jr.
Model 221
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Popular 2-Element Thunderbird
Model 390
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Dept. BA, 8601 Northeast Highway Six, Lincoln, NE 68507
402/464-9151 Telex 48-6424
Distributed in Canada by LECTRON RADIO SALES, LTD. 211 Hunter Street West, Peterborough, Ontario

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DON'T MISS
HR REPORT
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COMPUTER KEYBOARD
$7.00 (as is)

Several styles on hand in poor condition, broken key/keys, broken case or no case, etc. Still a good value at $7.00 for parts, switches, and each has encoder board in base.

2N2152	45 volt	170 watt	PNP-G	$1.00
•2N3713	80	150	NPN-S	1.00
•2N3773	160	150	NPN-S	.75
•2N3789	60	150	PNP-S	.75
2N5301	40	200	NPN-S	1.25
•2N5301	40	200	NPN-S	1.00

•Removed from used equipment

TRANSFORMERS

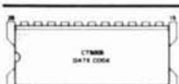
BRAND NEW, 115 volt AC input. OP - AMP XFMR, out puts: 16 VCT ½ amp, 17 VCT ½ amp. $3.50

FILAMENT or BTRY CHARGER XFMR

output of 18 volts at 4.5 amp $3.50

CALCULATOR KEYBOARD

Brand new keyboards for hand held calculators. Two styles available.
One for use with calculator chip CAL TEX 5001-5002-5012 or MOSTEK 5010-5012.
Another for use with Gen. Inst. chip C500.
Priced at $8.00 each or two for $15.00.



CT 5005
CALCULATOR CHIP

Single MOS chip with all logic required for 12 digit 4 function desk top calculator with extra storage register for memory or constant. Multiplexed 7 segment outputs for LED, Incandescent, Fluorescent, or Gas Discharge displays. Brand new, bargain priced, with specs.
$8.00 each, 2 for $15.00

HP LED DISPLAYS

Brand new 4-on-a-strip LED readouts. End-butt two strips and come up with 8 digit readout. An unheard of Super Value . . . $8.00 per strip, 2 strips $15.00
Another strip . . . this one a Clock Chip readout. 2 digits . . . a space . . . and 2 more digits. Just right for a clock reading hours and minutes. This one only $8.00

313,344 CORE MEMORY $125.00

From SPECTRA computer, visually OK. 64 x 68 x 4 x 18 core stack. Figures out to 35K Byte.

LED 7 SEGMENT READOUT

Similar to MAN-1. Factory seconds but functionally OK. Fit 14 pin DIP socket.

7 segment w/left decimal #LED-A-L $3.00
7 segment w/right decimal #LED-A-R 3.25
7 segment no decimal #LED-A 2.75

Above LEDs—7 for the price of 5
Socket for above, gold plated leads 3/1.00

IC SALE YOUR CHOICE 3 for $1.00

µl 900 BUFFER TO-5
µl 914 DUAL 2 INPUT GATE TO-5
µl 923 JK FLIP FLOP TO-5
µl 926 Hi speed JK FLIP FLOP TO-5
µl 931 JK/RS FLIP FLOP (DIP)
10 pin socket for TO-5 IC 3/1.00

GIANT NIXIE B7971

Used $1.00 Brand New $2.00
With schematic for GIANT clock.

COMPUTER TAPE DECK $75.00

Takes ½ inch tape, made by Computer Entry Systems. Visually ok, with electronics, no data available.

LASER DIODES, new listing just arrived, send SAE.

CMOS 4814 HEX INVERTER

CMOS HEX INVERTER, dual inline package. 3-18 volt range, dual diode protection against static charge. Dielectrically isolated complimentary MOS. $1.00 each 12 for $10.00

DUAL 16 BIT MEMORY

Dual 16 bit memory, serial MOS by Philco TO-5 case, brand new with 2 page specs.
#PLR 532 $1.00 each $10/12

2048 BIT MOS MEMORY

2048 bit MOS LSI random access memory NEC 6003. All inputs except clock are TTL compatible. 2048 word by 1 bit. 22 pin ceramic dual-in-line. With specs.
$9.00 each 2 for $17.00

ASCII KEYBOARDS LIKE NEW $45.00

From Raytheon, with encoder board in base, output on blue ribbon connector. This is the same keyboard we sell at $50 except this one has no case. 5 extra function buttons each side. Price includes shipping world wide.

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The new TS-520 is the transceiver you have wanted, but could not buy until now. It is a non-compromise, do everything, go everywhere 5 band transceiver for SSB or CW that performs equally well at home, in an automobile, airplane, boat or trailer. The TS-520 features built-in AC power supply, built-in 12 volt DC power supply, built-in VOX with adjustable gain delay and anti-VOX.

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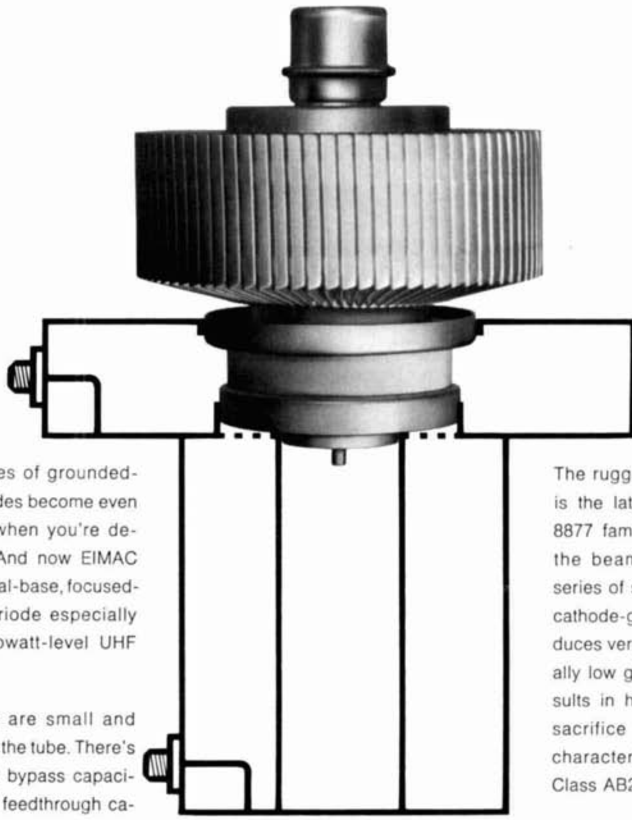
Simplify UHF circuits with EIMAC's 8938 high mu triode.



All the advantages of grounded-grid, high-mu triodes become even more important when you're designing at UHF. And now EIMAC introduces a coaxial-base, focused-beam, high-mu triode especially designed for kilowatt-level UHF applications.

At UHF, cavities are small and closely coupled to the tube. There's no room for bulky bypass capacitors, rf chokes, or feedthrough capacitors. With the 8938 in cathode driven (grounded-grid) service, there's no need for the grid circuit bypass capacitor; and no need for screen capacitors, bias or screen power supplies and associated decoupling circuitry. The internal tube structure is simple and the surrounding circuitry is much less complicated.

The rugged, ceramic/metal 8938 is the latest addition to EIMAC's 8877 family of tubes. Because of the beam focusing action of a series of strip electron guns in the cathode-grid region, the 8938 produces very high mu with exceptionally low grid interception. This results in high power gain with no sacrifice of low intermodulation characteristics in cathode-driven Class AB2 amplifier service.

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