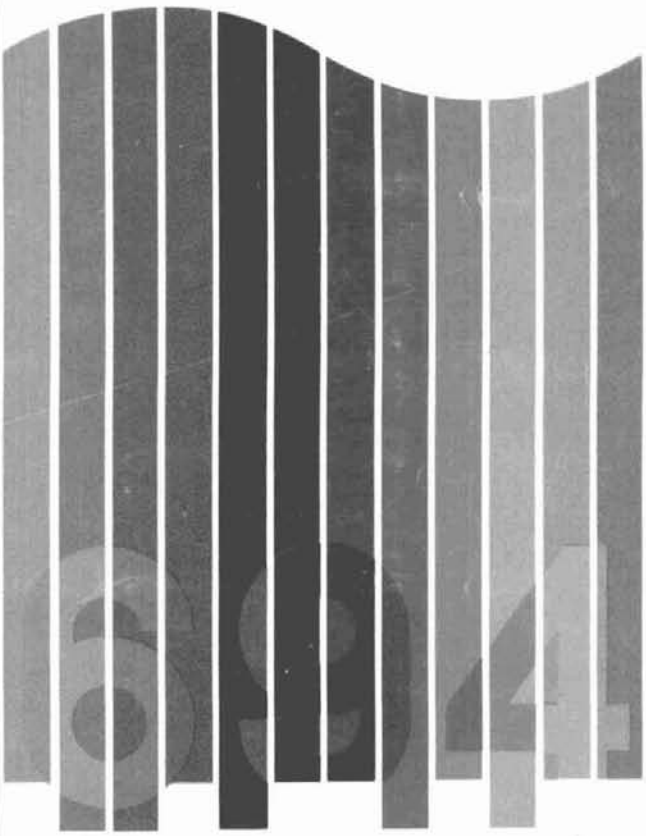
$2.00

ham radio

magazine

JANUARY 1979

two-meter frequency synthesizer



Shown with accessory touch tone pad

Top view, showing controls

800 channels in the palm of your hand

Tempo presents the S1 SYNCOM ...the world's first synthesized 800 channel hand held transceiver

This amazing pocket sized radio represents the year's biggest breakthrough in 2-meter communications. Other units that are larger, heavier and are similarly priced can offer only 6 channels. The SYNCOM'S price includes the battery pack, charger, and a telescoping antenna. But, far more important is the 800 channels offered by the S1. The optional touch tone pad shown in the illustration adds greatly to its convenience and we have available a 30 watt solid state power amplifier designed to give the SYNCOM S-1 the flexibility of operating as a mobile and base station as well.

SPECIFICATIONS

Frequency Coverage:	144 to 148 MHz
Channel Spacing:	Receive every 5 kHz transmit simplex or ±600 kHz
Power Requirements:	9.6 VDC
Current Drain:	17 ma-standby 400 ma-transmit
Batteries:	Ni-cad battery pack included
Antenna Impedance:	50 ohms
Dimensions:	40 mm x 62 mm x 165 mm (1.6" x 2.5" x 6.5")
RF Output:	Better than 1.5 watts
Sensitivity:	Better than .5 microvolts

SUPPLIED ACCESSORIES

Telescoping whip antenna, ni-cad battery pack, charger.

OPTIONAL ACCESSORIES

Touch tone pad, tone burst generator, CTCSS sub-audible tone chips Rubber flex antenna.

Price ... $349.00 (or with touch tone pad ... $399.00)

Tempo also offers a complete line of solid state power amplifiers, pocket receivers, the FMH-2, 5 & 42 portables, the VHF/ONE PLUS mobile transceiver, and the FMT-2 & FMT-42 remote control mobile transceiver. All available from Tempo dealers throughout the U.S. Call or write for full information.

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Henry Radio

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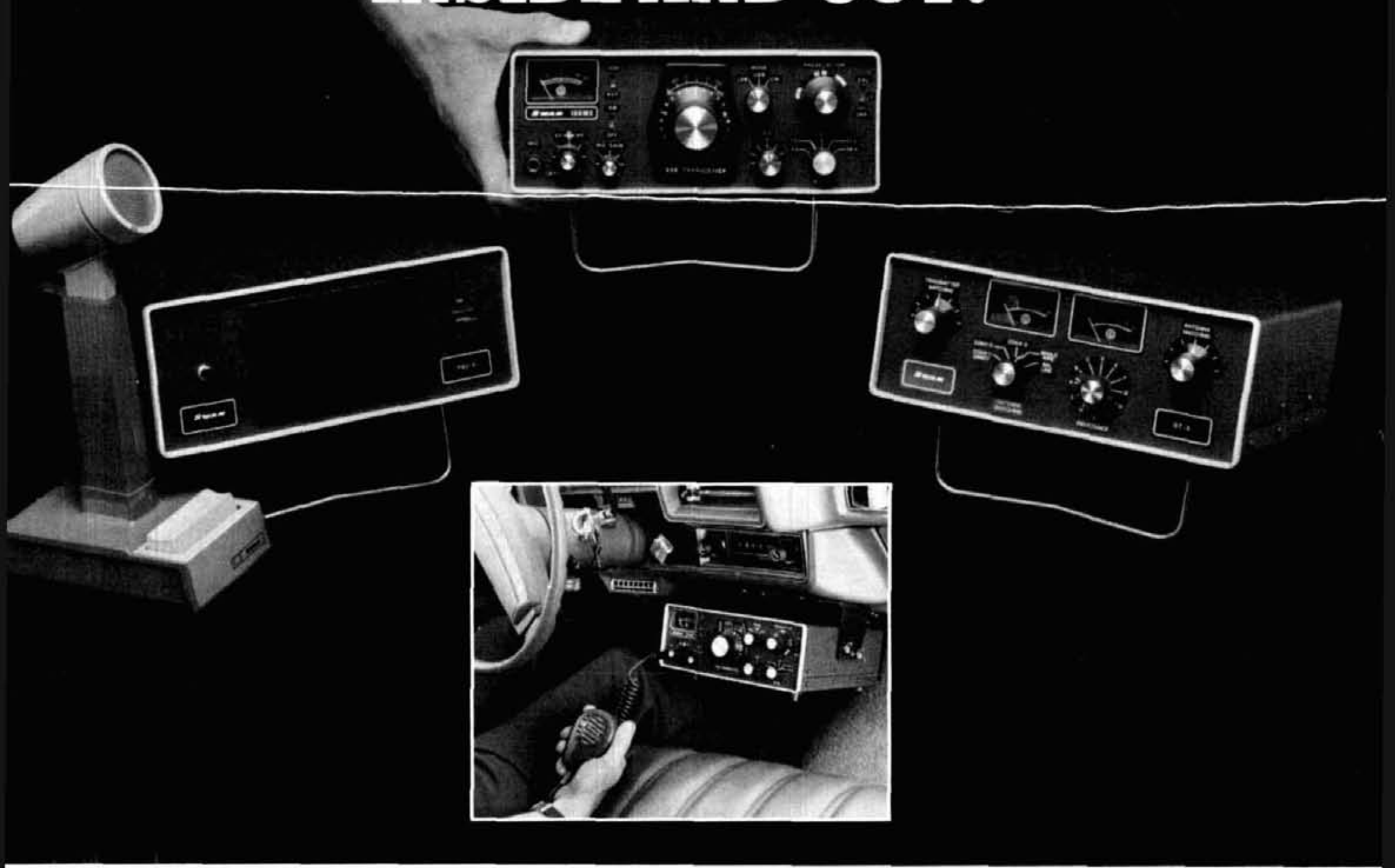

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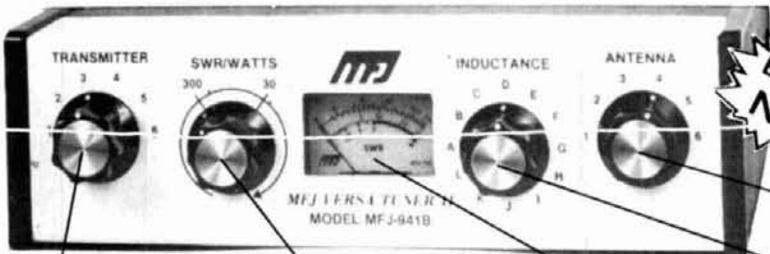
This NEW MFJ Versa Tuner II . . .

has SWR and dual range wattmeter, antenna switch, efficient airwound inductor, built in balun. Up to 300 watts RF output. Matches everything from 1.8 thru 30 MHz: dipoles, inverted vees, random wires, verticals, mobile whips, beams, balanced lines, coax lines.

MFJ LOWER PRICES!

NEW, IMPROVED MFJ-941B HAS . . .
- More inductance for wider matching range
- More flexible antenna switch
- More sensitive meter for SWR measurements down to 5 watts output



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Transmitter matching capacitor. 208 pf. 1000 volt spacing.

Sets power range, 300 and 30 watts. Pull for SWR.

Meter reads SWR and RF watts in 2 ranges.

Efficient airwound inductor gives more watts out and less losses.

Antenna matching capacitor. 208 pf. 1000 volt spacing.

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A SWR and dual range wattmeter (300 and 30 watts full scale) lets you measure RF power output for simplified tuning.

An antenna switch lets you select 2 coax lines direct or thru tuner, random wire/balanced line, and tuner bypass for dummy load.

A new efficient airwound inductor (12 positions) gives you less losses than a tapped toroid for more watts out.

A 1:4 balun for balanced lines. 1000 volt capacitor spacing. Mounting brackets for mobile installations (not shown).

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ANTENNA SWITCH lets you select 2 coax lines direct or thru tuner, wire/balanced line, dummy load.

You can tune out the SWR on your dipole, inverted vee, random wire, vertical, mobile whip, beam, quad, or whatever you have.

You can even operate all bands with just one existing antenna. No need to put up separate antennas for each band.

Increase the usable bandwidth of your mobile whip by tuning out the SWR **from inside your car.** Works great with all solid state rigs (like the Atlas) and with all tube type rigs.

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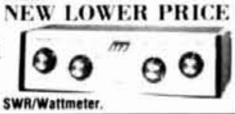

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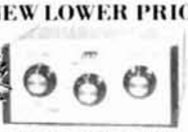

Same as MFJ-901 but less balun for balanced lines. Tunes coax lines and random lines.

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More Details? CHECK—OFF Page 118

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James R. Fisk, W1HR
editor-in-chief

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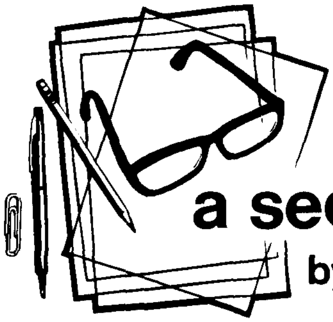


a second look

by Jim Fisk

As the editor I would like to think *that our articles have more effect on you, the reader, than* anything else; if not the most immediate effect, certainly the longest lasting. To be completely realistic, however, the one department which has the greatest impact on readers is circulation. If your issue is mangled by the Postal Service, or is late in arriving, or doesn't come at all, little time is wasted in letting our Circulation Manager know about it! I would hope that our response is just as immediate.

In the magazine business the word "fulfillment" is used to describe the internal business procedures which ensure that you get your mailed copy each and every month of your paid subscription. All magazines use a computer for this task, and we're no different. In the past all subscription orders were keypunched here in Greenville, and the punched cards were sent on to a computer house in Boston which filed the information on magnetic tape in zip code order. That two-step procedure has worked well for a number of years, but the growth of *ham radio* and the introduction of our sister publication, *Ham Radio Horizons*, has begun to strain the system. To both reduce errors and improve service to our subscribers, we recently contracted with a professional magazine circulation fulfillment service to do the entire task. That means that the subscription information must be transferred from one computer to another.

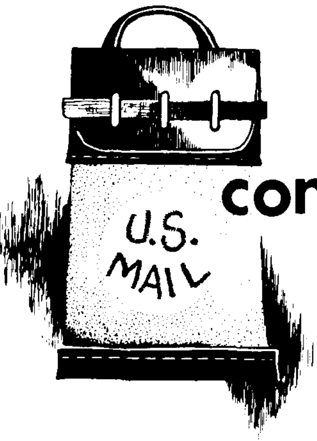
If this were a perfect world the changeover would go without a hitch, but Murphy's Law being what it is, there almost certainly will be some mistakes and garbled digits. We have instituted every safeguard we have available, but when you are faced with the humongous task of transferring nearly 50,000 names, callsigns, addresses, and subscription expiration dates, a few errors are inevitable. As the old saying goes, "Computers are not perfect — they're only as smart as the data given to them!"

We have been laying the groundwork for this changeover for several months, so we don't foresee any *major* problems. However, if your address label is garbled in the data transfer, please write to Ham Radio, Subscription Fulfillment Service, Post Office Box 711, Whitinsville, Massachusetts 01588. A correction will be made just as quickly as possible.

Although all subscription renewals, changes of address, and the like are to be mailed directly to our fulfillment service in Whitinsville, all correspondence to our editors or advertising department must be sent to our offices in Greenville. In the past, when readers have written to us about a subscription matter, they have often taken that opportunity to pose a question to our staff, or to comment on one of our previous articles. Such comments and questions are immensely useful as we plan future material for the magazine, but in the future such questions and comments should be separated from subscription matter and mailed directly to Greenville. Otherwise our staff won't have the benefit of your suggestions.

If you have an occasion to write to our fulfillment service in Whitinsville, please be patient (for fastest service, be sure to include the mailing label). Just remember that the computer does its work several weeks before the magazine goes into the mail, so there is considerable lead time involved (up to six weeks). This presents a problem for us, too, because we won't know a mistake has been made until you tell us about it, and we won't be certain the problem has been corrected until the computer prints the address labels for the next issue. However, with patience and understanding from you, our readers, the task will go much more smoothly. Thank you for your help.

Jim Fisk, W1HR
editor-in-chief



comments

bandspreading techniques

Dear HR:

The suggestions by Robert Heider, WØEJO, on a different form of standard capacitor ("Bandspreading Techniques," February 1977) are deserving of some comment.

The technique of using a guard for accurate calibration is a good one, but it must be used with care. The following points apply:

1. Careful examination of the referenced article's **fig. 6** will show the variable insulated from the case and thus guarded if the case ground is used.

2. Guard circuits must be used with bridges designed for that purpose (see, for example, *Electronic Measurement* by Terman and Pettit, McGraw-Hill, 1953, pages 102, 103).

3. Guard circuits used with "ordinary" bridges, Q Meters, etc., will simply include the coaxial cable capacitance. In this case it would be better to use *two* coax cables, one on each capacitor terminal, in order to halve the stray capacitance. Cables should remain in place for resonating with small values of C, since they contribute around 10 to 20 pF shunt.

Any sort of coax at high frequencies (about 1 MHz or above) will begin to show transmission line effects. A couple of feet of coax at 30 MHz will change calibration at the low end of the C range, compared with measurements made at 3 MHz. The series inductance addition was implied when the article suggested "heavy wire and short lengths."

It's surprising that even pros and old timers forget inductance of connection. Small inductance of leads makes the original noise bridge wideband. The largest stray inductance in the Hart bridge is the potentiometer arm connection, physically variable due to mechanical rotation. The arm is effectively balanced to ground on both sides of the bridge into the vhf region.

Leonard H. Anderson
Sun Valley, California

Dear HR:

After reading the September issue of *ham radio*, I feel the urge to write. That one issue paid for the whole year's subscription! The article by W7VK on CATV cable fittings was a godsend to me — I've had twelve 1/2-inch-cable to SO-239 fittings on order for five months, at $7.50 each. I called them up and said send my money back.

The article by K1XX of your staff gave me the "big answer" for matching 75-ohm hardline. Thanks guys!

By the way, when preparing hardline for use with fittings that terminate in a type N female, you must file the end of the center conductor into a round-nosed bullet shape, because the square end will spread and break the female pin on the cable side of the fitting. When buying male type-N connectors, be advised that the Amphenol #82-61 is a 50-ohm connector, and the center pin will break the female pin in a 70-ohm hardline fitting. For the 70-ohm connector the Amphenol part number is 82-84, and, apparently they are not a stock item, at least around here. The foregoing tips cost me $22.50 to learn. Pass the word, and save others some money.

Thanks again for a great magazine, and if you would like some hardline, look me up. I've got a bunch!

Don Ryan, WB4NND
Virginia Beach, Virginia

high resolution hf synthesizer

Dear HR:

The article in the August issue, "High-Frequency Resolution for an HF Synthesizer," describes a principle which is used in the Collins 651S1 receiver for which Collins Radio has a patent. While this system is apparently very attractive at first glance, it has the following disadvantages:

1. Because of the frequency selection, a large number of birdies are present if filtering is inadequate.

2. The theoretical high-speed locking is degraded because of the algebraic logic. This slows down the synthesizer so much that it can't be used efficiently for search operation. In the 651S1 receiver Collins engineers used an out-of-lock detector which mutes the receiver for virtually all tuning.

Finally, I would like to point out that my company holds the patent for the combination up/down counter with optical shaft encoder which was suggested for frequency synthesizer control (patent 97780, issued July 13, 1962).

Ulrich L. Rohde, DJ2LR
Rohde & Schwarz Sales Company
Fairfield, New Jersey

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...and, it's a combination that's hard to beat if you're looking for optimum versatility in a 2-meter FM transceiver. Together, the TR-7600 and RM-76 *offer you the following:*

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- Digital frequency display (large, bright, orange LEDS).
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- 10 watts RF output (switchable to 1 watt low power).

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- Store frequencies in six memories.
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- Stop scan (with HOLD button).
- Cancel scan (for transmitting).
- Scan for busy or open channel.
- Select repeater mode (simplex plus transmit frequency offset, minus offset, or one memory transmit frequency).
- Select transmit offset (±600 kHz / ±1 MHz).
- Operate on MARS (143.95 MHz simplex only).

- Display indicates frequency (even while scanning) and functions (such as autoscan, lower scan frequency limit, upper scan limit, error, and call channel).

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RUSSIA'S "RS" SATELLITES ARE UP and operating after a successful late October launch. Simultaneous beacon signals at about 29.400 MHz have been copied from both satellites. The uplink is 145.88-145.92 MHz with a 29.36-29.40 MHz output. The orbit of the RS satellites is considerably higher than that of any of the OSCARs, about 1050 miles. This should increase range 300-400 miles, with passes about three or four minutes longer than those of OSCAR 7. The orbital period is just over 120 minutes and its equatorial inclination about 83°, resulting in an orbit-to-orbit increment of just over 30°. Saturdays and Sundays will be the only days open for general use, with Wednesdays "educational days" and the rest of the week for scientific work. There is suspicion that RS's general use and educational days are Moscow time which is three hours ahead of GMT.

Daily RS News Bulletins, first in Russian (phone and CW) and then in English (CW only), are being sent on 7040 kHz at 0900Z by satellite command station RS3A. Radio Moscow broadcasts RS satellite news in English on 7165 kHz at 0130Z Sunday (Saturday evening, U.S. time).

REVELATIONS THAT AMATEUR RADIO was a principal communications tool of the People's Temple have heightened Amateur sensitivity to abuses of the bands. FBI agents, concerned about possible violent aftermaths of the carnage in Guyana, have been talking to a number of Amateurs who had worked or monitored Temple stations. The FBI would like tapes or transcripts of any communications from those stations. Any Amateur able to provide such information should contact the nearest FBI office.

NO HARMFUL NONTHERMAL EFFECTS were found to result from low-level microwave radiation by researchers reporting their results to the recent Symposium on Electromagnetic Fields in Biological Systems in Ottawa, Canada. More than a third of the 60 papers presented were on the effects of microwave radiation on various physiological systems, and not one of them reported finding any adverse effects other than heating from low-level radiation.

RF INTERFERENCE NEAR THE FCC'S monitoring stations is the subject of a new Notice of Proposed Rule Making, General Docket 78-365. In this proposal, the FCC suggests that radio operators in proximity to an FCC monitoring station consider what effect their operations may have on that station, and that they should consult with the monitoring station about their operations. The Notice would not require such consultation, however, but may indicate plans for more stringent future regulations such as those proposed below. Comment due date for the NPRM is January 22.

A Radio Quiet Area that now includes large areas of Virginia and West Virginia should also be applicable to Amateur Service and Class A CB operations, the Commission proposed in SS Docket 78-352. The area in question surrounds the National Radio Astronomy Observatory and the Naval Research Laboratory at Green Bank and Sugar Grove, West Virginia, within 39°15' and 37°30' north latitude and 78°30' and 80°30' west longitude. Only repeater operations would be affected, with operators required to consult with the director. Comments on this NPRM are due by February 1.

Relaxation Of CW Requirements for handicapped Amateur Radio applicants (FCC General Docket 78-250) seems to have brought more negative than positive response from the handicapped.

Comment Due Date on the docket has been extended to March 30 at the request of the Disabled American Veterans.

MORE ENCOURAGEMENT FOR AMATEUR RADIO comes from Geneva, following completion of a month-long WARC Special Preparatory meeting. The Amateur Service was well received by the 750 or so delegates (about 40 of them Amateurs), who represented 85 nations as well as dozens of recognized organizations, including the IARU. The meeting did not address such specifics as proposed frequency bands, but rather was directed toward broad topics such as needs, contributions, and the like. The results of the meeting — over 100 assorted documents — consisted of various recommendations and "conclusions."

For The HF And VHF Bands, the preferred parts of the spectrum for various types of Amateur operations were discussed, along with the desirability of exclusive Amateur allocations. The prospects of sharing with services such as radio location, which could provide additional frequencies for Amateurs with little or no significant interference, were also considered.

That Such Topics were discussed and adopted in this formative period without opposition is an encouraging sign that Amateur Radio will do well at next year's conference. It also indicates that the preparatory efforts made throughout the Amateur Radio world over the past few years are starting to pay off.

ARRL WILL CHALLENGE the FCC's linear amplifier ban in a formal court suit, the League's executive committee agreed at its mid-November meeting in Newington.

SAM HARRIS, KP4DJN/W1FZJ, passed away Saturday, November 4, at Arecibo, Puerto Rico. Among Sam's many accomplishments were the first Amateur Radio moonbounce contact (with KH6UK) and the first practical parametric amplifier. Sam was VHF editor for *QST* from 1960 through 1967, and served in the same capacity for *CQ* from 1955 to 1960.

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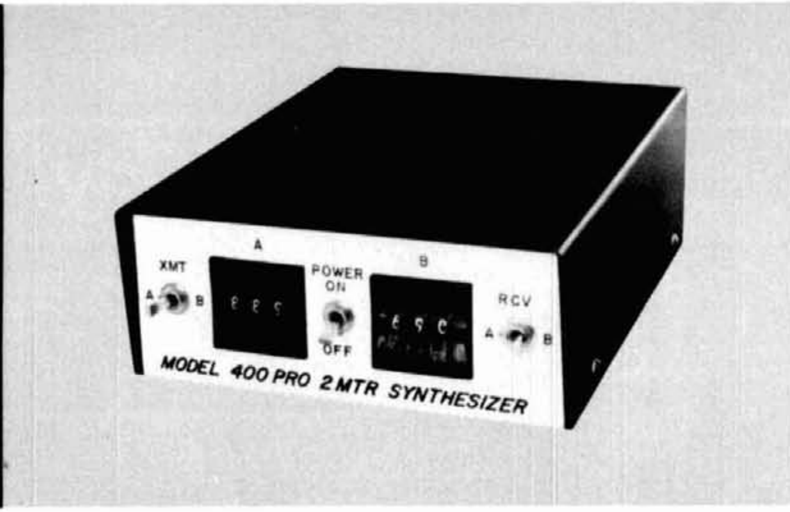

800-channel 2-meter synthesizer

A 400-channel 2-meter synthesizer featuring single-board construction, 15-kHz splits, and multiple output frequencies

Back in 1975, after operating a converted Motorola 80D for several years, I decided to move up to a more versatile rig that I could synthesize and also use mobile. I looked at the available commercial rigs and synthesizers, every construction article I could locate, and talked to fellow hams who had gone this route. I found several rigs I liked, but no synthesizers; so, I decided to buy a rig (an HW202) and build a synthesizer. My first impulse was to build one that had appeared in a magazine construction article. I studied the circuit and started trying to locate parts, becoming quickly discouraged. After talking with a local ham who built a synthesizer from the same article, I was further discouraged.

At this point, I decided to design and build from scratch. Having found several rigs that I liked, I felt the synthesizer should be universal enough that I could simply reprogram the i-f offset and output frequency for another rig. In addition I wanted only one crystal oscillator, since that would reduce the stability problems and eliminate spurious outputs associated with mixers. I also wanted the entire synthesizer on one board; parts had to be inexpensive and easy to get. The end product was called the "400 PRO" (400 channels receive, 400 channels transmit with Programmable Receive Offset).

circuit description

The crystal oscillator, as shown in **fig. 1**, determines the overall frequency stability of the synthesizer. The crystal is a 1-MHz, parallel resonant cut for 32-pF load capacitance. For temperature stability, the crystal tolerance should be no more than .003 per cent from −23.5 to 66 degrees C (−10 to 150° F). U5 is a 7400 TTL NAND gate used as the oscillator.

U2, U3, and U4 divide the 1-MHz frequency by 600, producing a 1.666-kHz reference for the phase detector. The phase detector is made up of U1, U24, and U25. These three ICs were chosen over the more popular MC4044 phase detector strictly for a cost savings of about $1.50.

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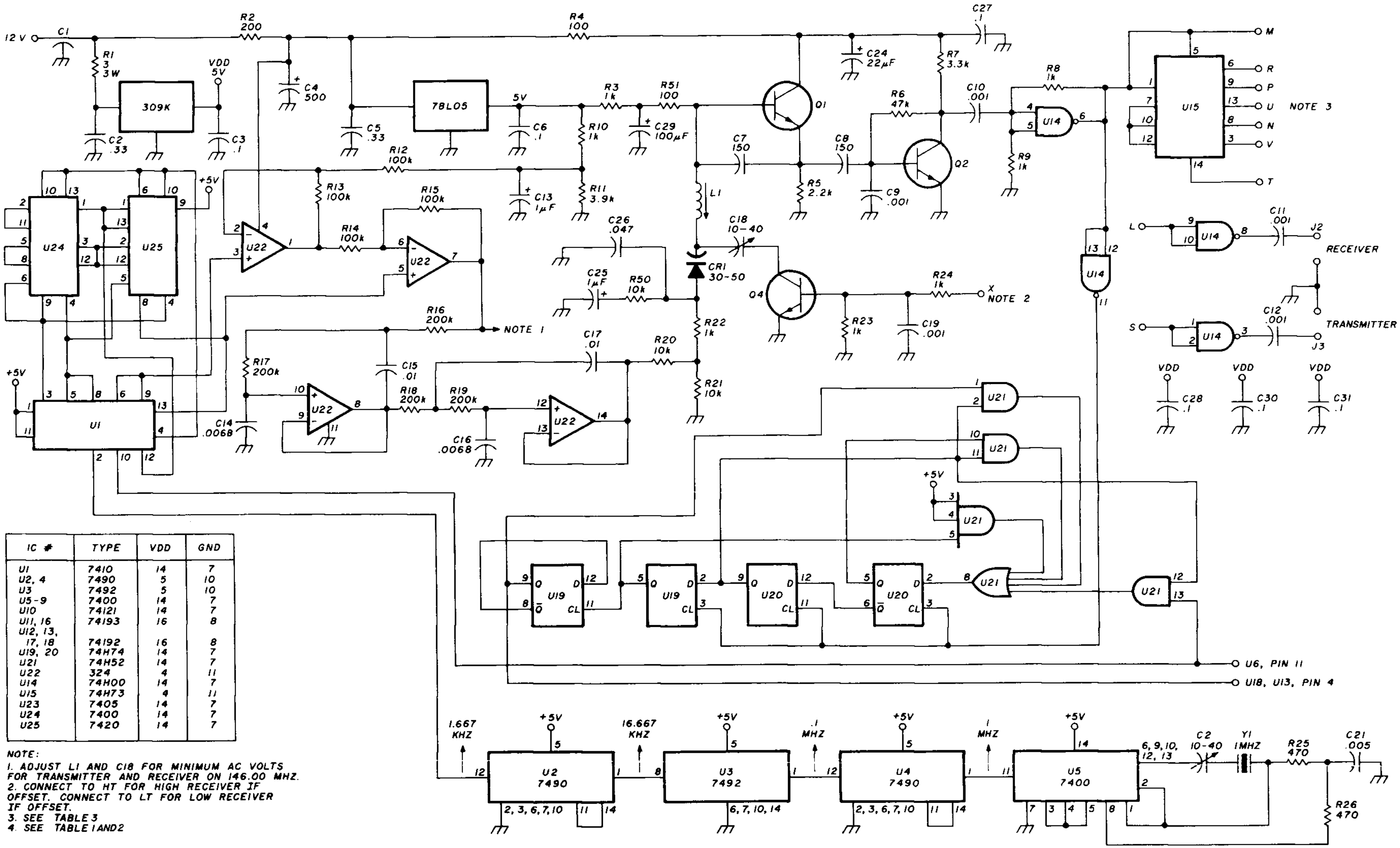


IC #	TYPE	VDD	GND
U1	7410	14	7
U2, 4	7490	5	10
U3	7492	5	10
U5-9	7400	14	7
U10	74121	14	7
U11, 16	74193	16	8
U12, 13, 17, 18	74192	16	8
U19, 20	74H74	14	7
U21	74H52	14	7
U22	324	4	11
U14	74H00	14	7
U15	74H73	4	11
U23	7405	14	7
U24	7400	14	7
U25	7420	14	7

NOTE:
1. ADJUST L1 AND C18 FOR MINIMUM AC VOLTS FOR TRANSMITTER AND RECEIVER ON 146.00 MHZ.
2. CONNECT TO HT FOR HIGH RECEIVER IF OFFSET. CONNECT TO LT FOR LOW RECEIVER IF OFFSET.
3. SEE TABLE 3
4. SEE TABLE 1 AND 2

fig. 1. Schematic diagram of the VCO, phase detector, active filter, and crystal divider portions of the two-meter synthesizer. Starting with the basic 1-MHz crystal frequency, the counters divide this down to 1.667 kHz for one input to the phase detector. The second phase detector input comes from pin 11 of U6 in the counter section (see fig. 2). To keep down costs, the phase detector in this synthesizer is composed of three individual ICs (U1, U24, and U25) instead of a single dedicated IC. The active filter, U22, attenuates the 1.667 kHz sidebands on the error signal from the phase detector before it is applied to the VCO. As discussed in the text, L1 and C18 should be adjusted for minimum ac signal on pin 7 of U22. The input to Q4 should be connected to HT for receivers with a high i-f offset, or to LT for a low i-f offset. The output from U15 can be strapped to provide the appropriate frequency for the transmitter to be synthesized.

The next portion of the circuit description may be a little more difficult to understand. There are two counter chains and a two-modulus prescaler which make up the dividers necessary to divide the VCO output frequency down to 1.666 kHz (see **fig. 2**). U19, U20, and U21 make up the two-modulus prescaler. This circuit is arranged to divide the VCO frequency by 10 or 11, depending on the dc level at pin 11 of U6. The output of the two-modulus prescaler is fed to both counter chains.

table 1. Connections for the i-f offset dividers for standard receiver offsets.

Receiver Offset	A	B	C	D	E	F	G	H	J	K	X
+5.5 MHz	HT	LT	LT	HT	0	HT	LT	LT	0	0	HT
−5.5 MHz	1	0	0	HT	0	HT	LT	LT	0	0	LT
+8.0 MHz	HT	LT	0	1	0	HT	0	0	0	0	HT
−8.0 MHz	HT	0	0	HT	LT	HT	0	0	0	0	LT
+10.7 MHz	HT	LT	0	1	0	1	LT	LT	0	LT	HT
−10.7 MHz	HT	0	LT	1	0	HT	LT	0	0	LT	LT
+12 MHz	HT	LT	0	HT	LT	HT	0	0	0	0	HT
−12 MHz	HT	0	0	1	0	HT	0	0	0	0	LT
+13.1 MHz	HT	LT	LT	HT	LT	HT	LT	0	0	0	HT
−13.1 MHz	HT	0	0	HT	0	1	LT	0	LT	0	LT
−11.7 MHz	HT	0	0	1	0	HT	LT	0	0	LT	LT

The channel select divider, U11, U12, and U13, is programmed to divide by 400 plus the thumbwheel switch setting. If a frequency of 146.94 MHz is selected on the thumbwheel switches (6.94 is selected since all channels are in the 140-MHz band), the channel select divider divides by 400 plus 694, which equals 1094. This method is used so that it is impossible to select a frequency out of the 144 to 148 MHz range. When in the transmit mode, the i-f program divider, U16, U17, and U18, is always programmed to divide by 1360. When in the receive mode, the i-f frequency of the receiver being used is subtracted or added to 1360. For example, if the receiver has an i-f frequency of 10.7 MHz, high side injection, then 107 would be added to the 1360 when in the receive mode. This is done by programming the i-f program counter to the HT and LT buss on the printed circuit board. The HT buss is high, or a logic 1, when in transmit; it is low, or a logic 0, when in the receive mode. The LT buss is just the opposite of the HT buss. A ground buss and a +5 volt buss are also provided for the counter inputs, which remain the same in transmit and receive. The i-f program counter can be programmed to divide by 1200 to 1599, which corresponds to minus 16.0 to plus 23.9 MHz in 100-kHz steps. See **table 1** for some standard i-f programming information and **table 2** for developing any i-f program.

table 2. Example of programming for the i-f offset counters. The BCD 800 and 400 are preprogrammed.

program terminal number	none	none	B	A	E	D	F	C	J	H	K	G
terminal BCD value	800	400	200	100	80	40	20	10	8	4	2	1
transmit value 1360	1	1	0	1	0	1	1	0	0	0	0	0
receive value 1467	1	1	1	0	0	1	1	0	0	1	1	1
your program	+5V	+5V	LT	HT	GND	+5V	+5V	GND	GND	LT	LT	LT

The output of U16, a negative-going 20 ns pulse, is lengthened to about 50 nS by U10. The subsequent output of U10 is inverted and buffered by U6 and used to load the counter chains with the jam inputs when the i-f program counter counts down to zero. The remainder of U6, which is connected as an RS latch, has a high output when the channel select divider counts down to zero, and a low output when the i-f program divider counts down to zero. When the output, pin 11, is low, the two-modulus prescaler divides by eleven; when pin 11 is high, the prescaler divides by ten.

Assume that the receive frequency is 146.94 MHz and the receiver has an i-f frequency of 10.7 MHz, with low-side injection. The i-f program divider would be set at $1360 - 107 = 1253$. The channel select divider would be set at $400 + 694 = 1094$. The outputs of U6 load both counter chains and set the prescaler to divide by eleven. After 1094 counts, the prescaler is set to divide by ten; the prescaler is reset to divide by eleven after $1253 - 1094 = 159$ counts. Therefore, the prescaler divides by eleven 1094 times and divides by ten 159 times. The frequency input to prescaler required to receive 146.94 MHz would be

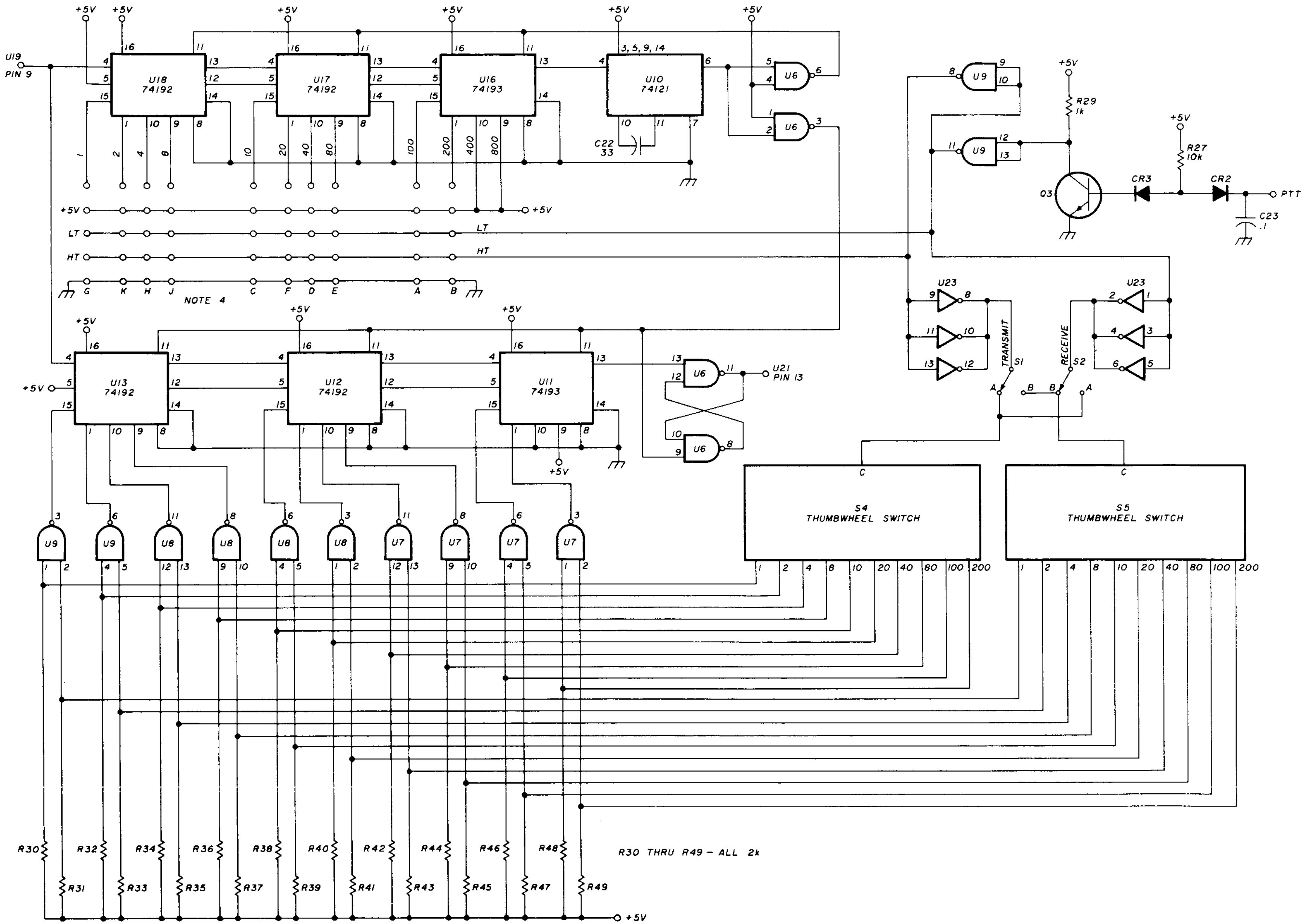


fig. 2. Diagram of the counter portion of the synthesizer. U11, U12, and U13 make up the channel select dividers, dividing by 400 plus the frequency selected. For example, *400 + 625 = 1052* for 146.52 MHz. The i-f program dividers, U16, U17, and U18, are normally programmed to divide by 1360 when in the transmit mode. When receiving, the dividers are programmed by jumpers to change the divide number according to the receiver i-f offset used.

$(146.94 \times 10^6 - 10.7 \times 10^6)/6 = 22.7066 \times 10^6$. Divided by $11 \cdot (1094) + 10 \cdot (159) = 1.66666 \times 10^3$, or the same as the output of the reference frequency divider.

These two signals, when compared by the phase detector, generate an error voltage which controls CR1. CR1, C18, and L1 make up the VCO tank circuit. The capacitance of CR1 can be varied from 30 to 80 pF, depending on the bias voltage. L1 is adjustable from 0.5 to 1 uH. L1 and C18 are adjusted to center the VCO frequency. Before adjusting L1 and C18, the i-f program counter chain should be pro-

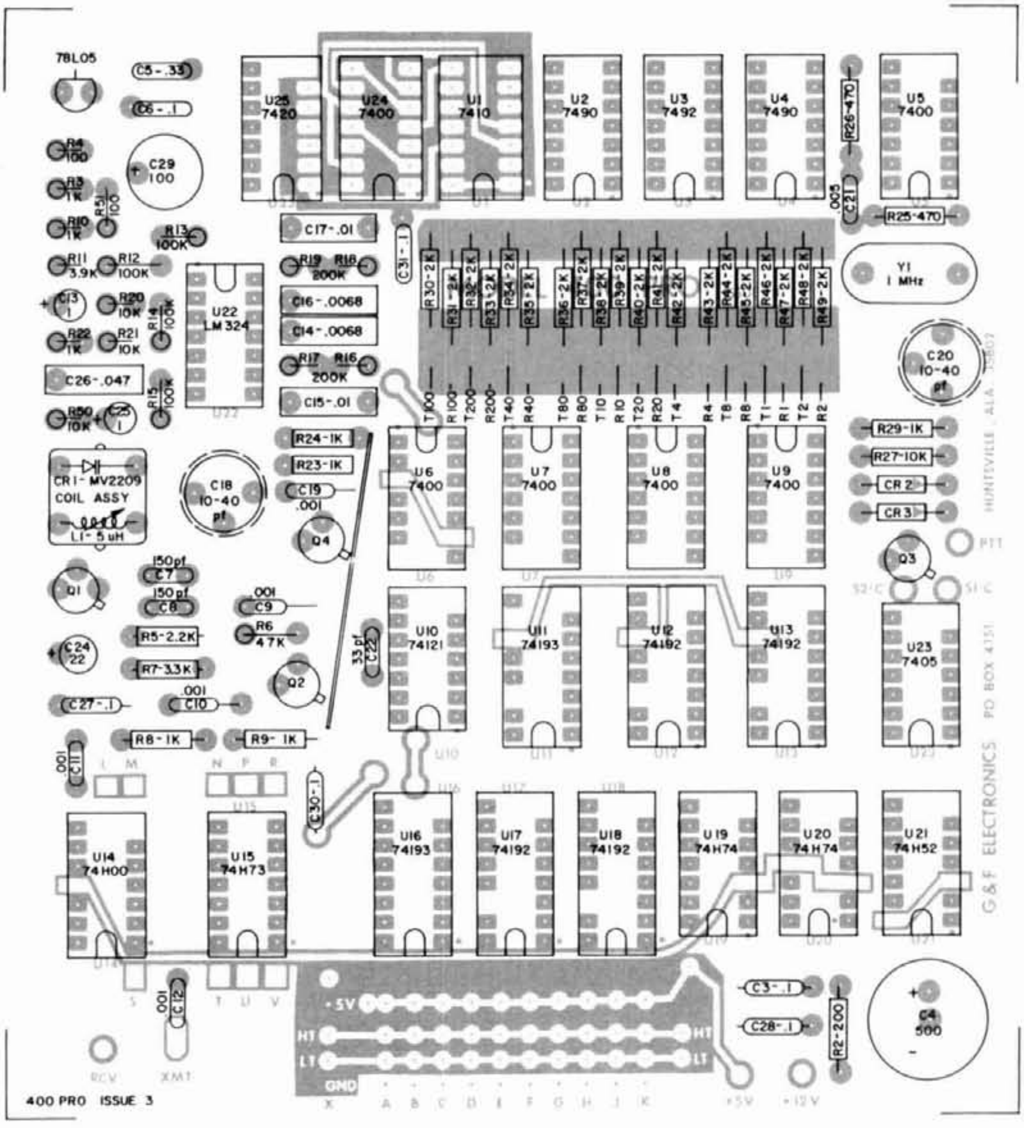


fig. 3. Parts placement diagram for the circuit board of the two-meter synthesizer. The jumpers for the output and i-f offset frequencies are explained in the tables.

the VCO. There are two outputs from the phase detector which drive pins 3 and 5 of U22. If no error voltage is generated, the level at pin 7 of U22 is 4 Vdc. If an error voltage is present, negative or positive pulses will be present at pin 7 of U22. The remainder of U22 is a four-pole, lowpass filter. At the output of the filter, the 1.666-kHz signal is 85 dB below the input.

The dc voltage from the filter biases the varactor, grammed for the i-f frequency of the receiver and the channel select divider should be set to 146.00 MHz. For receivers with low-side injection, adjust L1 in transmit and C18 in receive mode for minimum ac voltage at pin 7 of U22. This can be done with an oscilloscope or ac voltmeter. Adjust L1 in receive and C18 in transmit for receivers with high-side injection. This adjustment is not critical and will affect only the frequency deviation of the VCO. Terminal X is strapped to HT or LT and adds C18 to the tank circuit when X is high. Q2 and U14 buffer the VCO and drive the two-modulus prescaler and U15, a dual J-K flip-flop which may be programmed to divide by two, three, or four. The output is buffered by U14 to drive the transmitter and receiver crystal oscillators.

The PTT input should be grounded during transmit. This turns Q3 off. Q3 is buffered by U9 and provides the HT and LT levels to drive the thumbwheels used for transmit and receive. This provides any split or simplex operation on any set of thumbwheels.

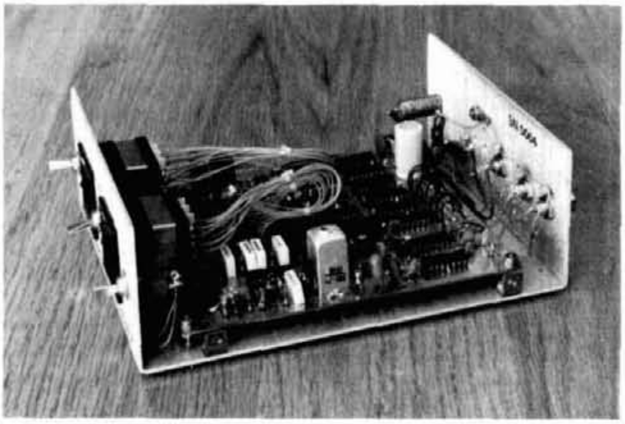
assembly

Assembly of the printed circuit board is straightforward and requires no special tools or techniques (it does require good grounding, however). Boards are available from the author* and will be by far the easiest route to go. If you prefer to lay out your own circuit board, care should be taken in the placement of components and traces to prevent the introduction of VCO whine and switching transients onto the signal lines. It is strongly recommended that a double-sided printed circuit board by used, as this is largely the secret to success in the virtual elimination of VCO shielding, the use of only one board, and the absence of "trash" on the output signal. Vector-type boards should not be used, because of the difficulty in attaining the high degree of shielding necessary. The very first 400 PRO built was on vector board. It was tough to get the output clean and it required two boards, one for the VCO and another for the rest of the synthesizer. It was also necessary to cover the entire VCO with a metal can and place a third copper-clad board between the two main boards, with everything securely grounded.

table 3. Connection to U15, the output divider, for different transmitter/receiver multiplication factors.

receiver multiplier	transmitter multiplier	jumpers
6	6	M-S, M-L
6	12	M-L, P-S, V-GND, R-HT
6	18	M-L, N-S, V-P, T-HT
6	24	M-L, N-S, T-HT
12	6	M-S, P-N, V-GND, R-LT
12	12	L-P, N-S, V-GND
12	18	U-L, V-N, P-S, R-HT
12	24	U-L, P-S, R-HT
18	6	M-S, L-N, V-P, R-HT
18	12	L-P, U-S, V-N, R-LT
18	18	L-N, V-P, N-S
24	6	M-S, L-N, T-LT
24	12	L-N, U-S, R-LT
24	24	L-N, P-S

Component placement and sizes should be kept as near as possible to those shown in the component placement drawing (**fig. 3**). All parts used, with the exception of the VCO coil and cover and copper pipes over C18 and C20, are available from most parts houses advertising in this magazine. For best results, IC sockets should not be used. However, if they are used, a good quality socket *is a must*. First-run ICs should be used if at all possible, as problems can be encountered with "discount house" ICs. As a general rule, most discount houses will quickly replace any bad IC. Nevertheless, replacement of bad ICs is little compensation, in many cases, for the misery encountered in finding them in a circuit.



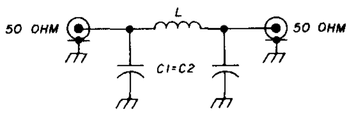
In this view you can see the i-f transformer can, which is used to shield the varactor and coil. Also notice that the board mounting technique provides four secure grounds.

A suitable source for the VCO coil and cover is the 6.5-mm (1/4-inch), four-terminal transformer used in the i-f of commercial fm receivers. Strip off the existing coil and wind 17 turns (close wound) of number 32 (0.2-mm) AWG enamel wire, terminating on two of the four terminals. (See **fig. 3** for the correct terminals.) The MV-2209 varactor should be connected to the other two terminals, and both the coil and varactor should be covered with Q-dope and then placed back in the can. The can mounting tabs should be soldered to the ground point on the printed circuit board. If the VCO coil slug is not tight, the VCO will become sensitive to mechanical shock. If this occurs, the output of the VCO will sound just like a microphonic tube on both transmit and receive. The solution to this problem is fairly simple: after final VCO adjustment, apply a drop of candle wax or

*Double-sided, plated-through, G10 printed circuit boards with complete instructions ($18.75), completely assembled and tested boards ($89.00), and coil assembly with MV2209 ($3.50) are available from G&F Electronics, P.O. Box 4151, Huntsville, Alabama 35802.

similar material onto the slug. Remember, if you should later change to a rig that has a different i-f offset, the VCO may require a touchup. Don't lock the slug down too tightly.

The covers over C18 and C20 were made from 9.5-mm (3/8 inch) copper tubing cut in 12.5-mm (1/2-inch) lengths and soldered to the shield side of the printed circuit board. Care should be taken to prevent the inside of the copper tube from shorting



FREQUENCY	L	C1=C2
6	3.3 µH	220 pF
8	3.3 µH	180 pF
12	2.2 µH	100 pF
24	1.0 µH	47 pF
48	.47 µH	22 pF
72	.33 µH	15 pF

fig. 4. Lowpass filter that can be used on the output of the synthesizer.

the capacitor to ground. A piece of thin Mylar or Teflon sheet wrapped on the inside of the tubing will serve as a spacer. The Mylar used in drafting departments for taping printed circuit board masters is excellent for this purpose. The tubing should be quickly soldered in place using a hot iron. A thin strip of copper 1 mm (0.03 inch) thick should be soldered in place on the component side between Q2, Q4, and U6, U10 as shown in **fig. 3**. This 5 cm × 1.3 cm (2 × 0.5 inch) shield is sometimes needed to prevent VCO whine. Since it is cheap and easy to install, one should be used as a preventive measure.

The enclosure shown in the photos was hand-made from 1.5-mm (0.062-inch) aluminum sheet and painted with enamel paint. The lettering was applied using a Leroy lettering set with black India ink. Press-type, dry-transfer decals will also work quite well. The lettered surface should be protected with a clear Krylon spray.

The enclosure shown in the photographs has no means of ventilation. Ventilation is recommended to reduce heat build-up, thus improving frequency stability. The unit shown was accidentally left on inside a closed vehicle on a 38°C (100°F) day with no ill effects, except for the fact that the cover became hot enough to burn your hand.

Most importantly, the box used should be one with good rf integrity. This usually means all metal with good metal-to-metal contact between pieces. Plastic panels should not be used, nor should metal boxes with vinyl contact coating. The Radio Shack box 270-254 is the most suitable commercially available one I found. It costs about $5.00 and has only one shortcoming: The front panel is thin-gauge aluminum which is a little too flimsy and thin for Digitran 2300-series thumbwheels. This problem can be corrected by gluing strips of aluminum behind the front panel and on each side of the thumbwheel switches to act as shims.

The printed circuit board should be mounted at all four corners with a good solid ground connection to the box. Make sure that your spacers do not extend beyond the copper pads provided on the circuit side of the printed circuit board, as this can cause portions of the circuit to short to ground.

The printed circuit board should be positioned such that the transmit and receive outputs are just below the rf output connections on back of the box. Lowpass filters should be used between the printed circuit board and rf output connectors (see **fig. 4** for values). If lowpass filters are not used, short pieces of buss wire (2.5 mm [1 inch] or less) should be used.

The 3-ohm, 3-watt resistor (R1) should be connected directly to the LM309K input pin and clamped against the rear panel for mechanical strength and heat transfer. C2 and C3 should be connected to the LM309K terminals and grounded to a lug under one of the 309K mounting screws (C2 and C3 should be ceramic). The +12 volt input should enter the box through a 0.01-µF feedthrough capacitor.

If needed, the PTT line can enter through a feedthrough capacitor. However, no situation has been encountered where an RCA phono jack with a 0.1-µF capacitor to ground would not suffice. All rf output connectors are RCA phono-type, but any good quality rf connector with a good ground connection will work well.

The thumbwheel switches used are the Digitran 2300-series. Any thumbwheel or rotary switch providing BCD output can be used. Lever-type thumbwheels were not used for fear of unintentional frequency changes caused by the microphone cord. Rotary switches were not used because the larger front panel required was not desirable.

programming the synthesizer

Jumper wires should be used to connect terminals

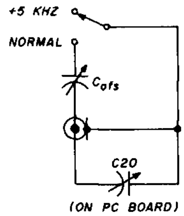


fig. 5. To use the synthesizer on repeaters that are on 15-kHz splits, the time base is shifted in frequency by the additional capacitor, C_{ofs}. This capacitor generates a time base error that shifts the output frequency the necessary 15 kHz.

A through K to the HT, LT, +5 volts, or GND buss to program the synthesizer to match the i-f frequency of your receiver. Terminal X should be connected to HT for receivers that use high-side injection, and connected to LT for receivers that use low-side injection. **Table 1** lists several i-f frequencies and the proper connections for programming. Receivers with i-f frequencies, other than those listed in **table 1**, can be programmed using the following example. **Table 2** lists the BCD values that correspond to terminals A through K. The left-hand column lists the transmit and receive values that should be programmed. The transmit value is always 1360. The receive value is determined by the receiver i-f frequency. If the receiver i-f frequency is 10.7 MHz with high-side injection, 107 should be added to 1360 for the receive value. The 800 and 400 values are prewired on the printed circuit board and do not have to be programmed. In the transmit frequency row, write the BCD value which equals 1360. In the receive row, write the BCD equivalent of the receive value. Under the receive row, write HT for all values which are 0 in transmit and 1 in receive. Write +5 volts for all values which are 1 in transmit and 1 in receive. Write GND for all values which are 0 in transmit and receive. These are the values which should be programmed to terminals A through K.

Output divider program is given in **table 3**. Transmit and receive divider should be the same as the crystal multiplier for your transceiver. Output divider programming terminals L through V are the square pads located at either end of U14 and U15.

interfacing

A proper interface between the 400 PRO and your transceiver is a must for satisfactory performance. With the 400 PRO, the transceiver's oscillator (transmit and receive) must operate as a buffer amplifier instead of an oscillator. The drive level at the transceiver must be the same as if a crystal were still being used. Drive level from the 400 PRO is in most cases higher than that of a crystal. It should be reduced, as required, by the addition of series resistance at the point of interface. Any additional interfacing components should be as close to the interfacing point (usually the crystal socket) as possible. Optimum results are obtained if connections are soldered at the interface point. Satisfactory results should be obtained by plugging into an unused crystal socket. If this method is used, insure that all mechanical connections are solid.

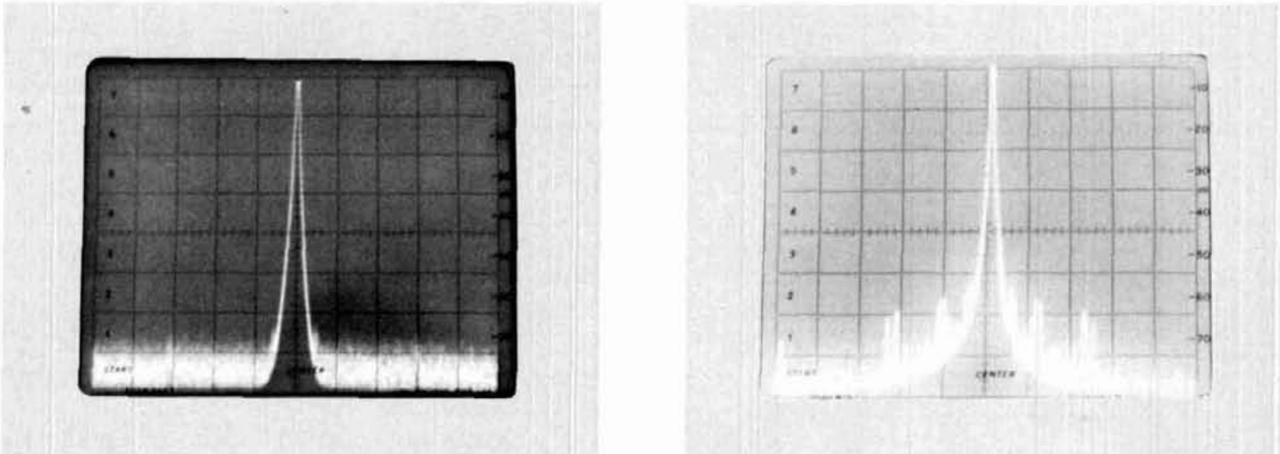


fig. 6. Output of the synthesizer as seen on the display of a spectrum analyzer. At left, the horizontal scale is 2 MHz/division, while the vertical is 10 dB/division; right, the horizontal scale calibration has been shifted to 200 kHz/division.

With some transceivers, one side of the crystal is switched with the channel selector while the other side is connected to ground through a trimmer capacitor. Interfacing with this type of transceiver is best accomplished by adding a solid chassis ground to which the 400 PRO ground (shield side of coax) should be connected. The center conductor is then connected to the switched side of the crystal socket (through the proper interfacing components).

The basic requirement for operation is adequate drive at the appropriate frequency, which need not necessarily be exactly the same as the crystal it replaces. For example, if your receiver requires a 48-MHz crystal (as does the HW202), it will work quite well with a 24-MHz signal. The oscillator will then act as a doubler. Other transceivers require a 15-MHz crystal, which is multiplied by nine. These oscillators will operate with a 23-MHz input multiplied by six.

The 400 PRO, as wired in this article, will work the entire two-meter band. Few transceivers are broad enough to allow full power output or maximum sensitivity across the entire band. Don't be alarmed if a couple of MHz is your limit. This problem is very pronounced with commercial-band radios such as Motorola and GE.

When interfaced properly, the transceiver will work just the same with the 400 PRO as with a crystal. If it does not, it is either not interfaced properly or other problems exist. The most common other problem is rf leakage into the 400 PRO. The symptoms of rf leakage are distorted or low frequency audio on transmit. This distortion may come and go when the equipment is moved. In some cases, movement of the microphone, rf or audio cables, nearby objects, or even people can cause the intermittent distortion. In severe cases, the movement of one's hand near the equipment can cause distortion. The most common cause is poor or missing ground connections. Signals can also be coupled in via either the transmitter, receiver, PTT, or the +12 volt line. Any problems entering on the +12 volt or PTT line can be eliminated by the use of feedthrough capacitors. Coupling through the transmitter or receiver lines can be eliminated by the addition of a lowpass filter inside the 400 PRO. In extreme cases, an additional lowpass filter may be required at the transmitter end of the coaxial cable. The filter can be the same as in the 400 PRO and should be mounted inside the transceiver at the point of entry; ground it well. If filtering is done after interfacing, recheck the drive levels.

The 400 PRO can be used in one crystal position, with crystals used in others. With this set-up, the 400 PRO should be turned off any time the transceiver is used in a crystal mode. Failure to do so can result in spurious output in the transmit mode and unwanted birdies in the receive mode.

Interconnecting cables between the 400 PRO and your transceiver should be a good quality 50-ohm coax; the miniature RG-174 works very well. *Never* use audio cable, shielded or unshielded. Good grounding is an absolute must. Short interconnecting cables are obviously best, but several 400 PRO's are now being used with trunk-mounted, commercial-band equipment. (I use one with a Motrac U43MHT.) Miniature coax is used between the dash-mounted 400 PRO and the trunk-mounted radio. One potential problem with commercial-band radios is high resistance in the tensile cord push-to-talk line. This manifests itself in the inability to switch the 400 PRO from receive to transmit. The problem can be corrected by either replacing the microphone cord or reducing the resistance such that Q3 will switch when the PTT button is pressed.

direct fm

Most transmitters are phase modulated instead of true fm. However, for those that are true fm, the 400 PRO will not simply plug into the crystal socket and function. The phase lock action of the 400 PRO will not allow the output frequency to be shifted. To solve this problem, the VCO in the 400 PRO must be direct-fm modulated. This is accomplished by applying audio from the transceiver directly to the 400 PRO VCO. Fm produced in this manner is of superior quality. The 400 PRO can be frequency modulated when used with either fm or pm rigs.

5-kHz offset

The 400 PRO was not designed for 5-kHz output steps. A very simple modification, however, can be made that will provide 5-kHz output increments. This is accomplished by the addition of a toggle-switch selectable capacitor (see **fig. 5**) which will alter the divide ratios. The change will result in an error of 34 Hz/MHz at the two-meter output frequency. For example, if the 400 PRO is set up for no error at 146.005 MHz, the transceiver will exhibit a 67-Hz error at each end of the band (144.000 to 147.995). When not in the 5-kHz mode, the 400 PRO will operate normally and will have no error caused by this modification.

The off-set capacitor shown in **fig. 5** can be mounted on the printed circuit board or at the toggle switch. Interconnecting cabling (RG-174) should be kept as short as is practical (15 cm [6 inches] or less).

The easiest method found for initial setup is to calculate the required transmit frequency, with and without +5 kHz off-set. With the off-set selected, adjust C20 for the required frequency. Switch back to the normal position and pull the frequency back down as required with C_{ofs}. You may have to repeat this procedure a couple of times. The transmit mode was chosen for initial setup because of the calculation — no i-f off-set is involved.

After the 400 PRO is interfaced to your rig and working properly, the same adjustment procedure can be used while monitoring your transmitter output frequency with a frequency counter. Once properly adjusted in the transmit mode, the receive frequency is automatically set and will require no further adjustment.

conclusion

Although many 400 PROs have been built and used with a variety of rigs, additional interfacing information is always welcome. If you encounter any unusual interfacing problems to which you find a solution, it would be greatly appreciated if you would jot down the details and mail them to me. By the same token, if you encounter problems you cannot solve, I will be glad to try to help you. The following information must be furnished: transmit and receive crystal formulas, multiplier arrangement, and a schematic. If you are going to have a problem with the 400 PRO, it will most likely be in interfacing it to your rig.

ham radio

optimizing and measuring fm deviation

Louder isn't necessarily better in an fm transmitter — intelligent use of the deviation control will produce maximum talk power per watt

In fm radio transmission, the louder the modulating signal into the microphone the greater the variation of the carrier from its center, or resting, frequency. Generally this also means a stronger audio signal at the detector of a properly tuned fm receiver. The amount of the plus or minus frequency swing is called *deviation*. Deviation is talk power, and that's good — most of the time but not always.

There are three conditions under which increased deviation is not to the user's advantage. First, FCC Regulation Part 97.65 limits the deviation to ±3 kHz on frequencies below 29.0 MHz and between 50.1 and 52.5 MHz. Deviation is limited to ±20 kHz for *all other* authorized Amateur Radio frequencies. Continued violation of the regulation could result in zero talk power. Get the message?

Second, particularly in the 2-meter band, interference between stations operating on different frequencies is minimized if the portions of the frequency spectrum used by each of the stations don't overlap. This is shown graphically in **fig. 1**. The amateur community long ago recognized the potential for a problem and used some of its better thinking to find ways for avoiding the interference. The solution is best seen in the band plans for 2-meter repeater operation, where the generally used frequencies are 10 kHz apart, corresponding approximately to a ±5 kHz deviation limit.

The decision to self-impose a 5-kHz deviation limit when the FCC was offering up almost four times that much wasn't entirely magnanimous. (Required band-

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width is approximately 2 × deviation + maximum modulating frequency. Thus, for a 3-kHz modulating frequency, and FCC permitted maximum deviation, the required bandwidth would be $\frac{40-3}{2} = 18.5$ kHz.) This becomes evident in an examination of the third condition, under which it's to the user's advantage to limit the deviation.

modulation index

In fm radio transmission, the total power radiated is independent of the modulation. When the carrier is modulated (deviated), power is transferred from the carrier to the intelligence sidebands. The amount of power that's transferred depends on the modulating-signal amplitude and something called the modulation index (MI). We noted previously that the achieved deviation varies with the modulating-signal amplitude. The modulation index is the ratio of the frequency deviation to the modulating-signal *frequency*.

For example, if a transmitter deviates 5 kHz with a modulating signal of 2 kHz, at some amplitude the modulation index would be $5/2 = 2.5$. The relationship between the relative amount of power in the carrier and sidebands and the modulation index is shown in **fig. 2**. It's evident that the maximum amount of power is transferred to the sidebands when the modulation index is approximately 2.4; that is,

$$MI = \frac{Dev}{F_m} = 2.4 \qquad (1)$$

audio bandwidth

Students of audio-frequency phenomena know that, although the full spectrum of human speech is between approximately 100 and 8000 Hz, only a small fraction of that range is normally used. If everything below 1000 Hz is filtered, comprehension is not affected, but the result is a mechanical, unnatural sound. If frequencies above 1000 Hz are filtered, the result is a varying amplitude mumble that's almost devoid of intelligence. As more and more of the frequencies above 1 kHz are permitted to pass, comprehension increases rapidly until about 1800 or 2000 Hz is reached. Comprehension then increases less rapidly until, by 3000 Hz, almost nothing is added to comprehensibility by increasing bandwidth. If **eq. 1** is examined in light of this:

fig. 1. With center frequencies 10 kHz apart, two fm stations will still experience some mutual interference if each modulates to 4.5-kHz deviation with a 1.5-kHz tone.

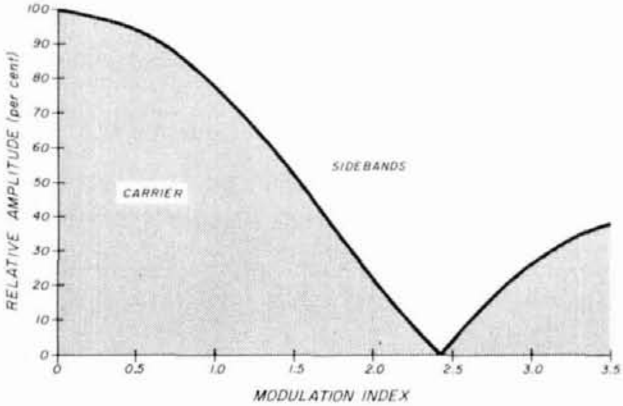


fig. 2. Relative amplitude of the rf power remaining in the carrier as a function of modulation index.

$$MI = \frac{Dev}{F_m} = 2.4$$

$$Dev = F_m \times 2.4 = (1\ kHz\ to\ 2\ kHz) \times 2.4 \qquad (2)$$

$$= 2.4\ kHz\ to\ 4.8\ kHz$$

Thus, the most effective way to use the rf power and obtain maximum readability is to hold the achieved deviation between about 2.5 and 4.5 kHz; the lower number for bass-voiced males, the higher number for tenors and sopranos. Thus it's possible at one and the same time to keep the FCC and fellow hams happy — or, at least, off your back — and to make efficient use of the rf power from the transmitter. Adjusting the transmitter to achieve the desired and maximum deviation isn't difficult. It consists solely of tweaking a couple of potentiometers while making a few measurements.

audio gain and deviation controls

Typically, the signal from the microphone is ac-coupled to a one- or two-stage audio amplifier; then to a clipper and filter, then to a deviation-level control stage, and finally to the modulator. Most, but not all, transmitters have a means of gain adjustment in the audio amplifier stage. All fm transmitters should have a potentiometer for controlling deviation-level set, or, maximum deviation. Really good matching of the microphone, the user's speech characteristics, and the transmitter can be accomplished only when both controls are present. If only a deviation-level set control is available a useful degree of optimization is still possible, although the user may have to experiment with different microphones to get the best match.

an analogy

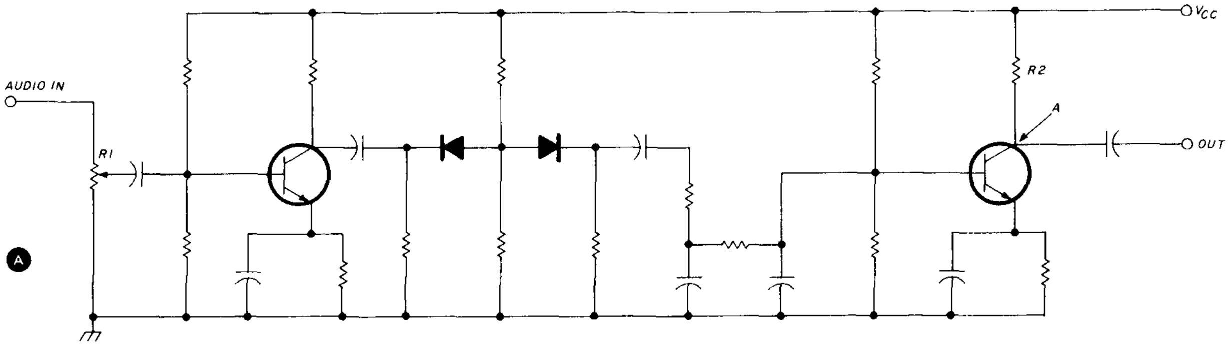
To visualize the interaction between audio gain control and deviation level set, it's convenient to use a simple analogy. Picture a small system made up of a water well, an electric pump, a faucet, and the connecting pipes. It's clear that until the pump is turned on no water will flow, faucet open or closed. Now, turn on the pump with the faucet closed and still no water flows. As the faucet is gradually opened, more and more water will flow until the maximum flow rate of the pump is reached. After that, further opening of the faucet results in no further flow increase.

Thus we see that the pump really determines the flow rate; the faucet can only limit it. And so it is with the audio amplifier and deviation-level controls. The amplifier is the pump; the deviation control is the faucet. The point is that the amplifier establishes the average deviation achieved during transmission. The deviation control provides a high side limit to the deviation.

setting the deviation

For best results, audio amplifier gain should be set to place the achieved deviation somewhere between 2.5 and 4.5 kHz for normal speech, as previously described; and the deviation level should be set to limit the deviation to 5 kHz on very loud sounds into the microphone. At the same time, care must be taken to avoid overdriving the audio amplifier so that speech fidelity will be maintained. Audio gain can be set only with an oscilloscope. A deviation meter is required for the remaining adjustments. The circuit for a simple, inexpensive deviation meter is described later.

Two representative audio input circuits are shown in **fig. 3**. One consists of discrete components; the other, an integrated circuit. The oscilloscope is connected to point **A**, and audio gain is varied with the setting of R1. Excite the microphone with a steady tone in a normal speaking voice. This can be done, for example, by saying "fo-o-o-ore," as on a golf course, while varying R1 until the audio peaks are *barely* flattened as seen on the scope. Even in the absence of an audio-gain control this is a good check. If it's necessary to holler into the microphone to get limiting, a new mike may be in order.



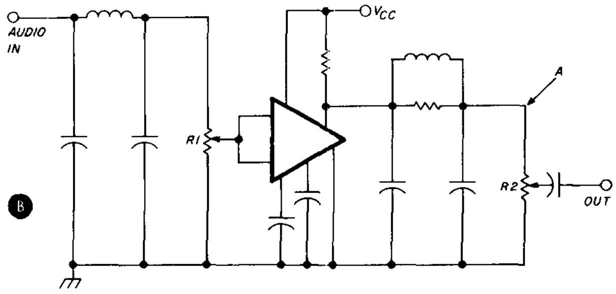


fig. 3. Typical fm-transmitter audio input circuits. Sketch (A) uses discrete components; sketch (B) uses an IC. R1 is for audio gain; R2 is the deviation-limit control. Oscilloscope is connected at point A in both circuits.

simple deviation meter

A minimal deviation meter consists of a suitable radio receiver and a calibrated, peak-reading voltmeter. The accompanying photograph shows such a device. It consists of the metering circuit shown in **fig. 4** and a commercial scanner. Most of the circuit is mounted on a 25.4 × 38 mm (1 × 1.5 inch) printed circuit board fitted into the scanner. Voltage is taken from the scanner power supply. The only modification to the scanner is the removal of a capacitor, as described later. The scanner function is not affected. Contained in the meter housing are the two switches, the calibration pot, and the smoothing capacitor. The exact layout of the printed circuit board depends on the transformer and the meter-input pot used, so it's not shown here. The layout isn't at all critical. Any fm receiver capable of precise tuning to the carrier frequency of the transmitter to be tested can be used. In many cases, no modification to the receiver need be made. At most, as discussed later, it may be necessary to lift, temporarily, one end of a capacitor to use the receiver.

component selection

None of the voltmeter component values are critical. The diagram represents what I had in my junk box. I salvaged the diodes from surplus computer boards. Those selected had the lowest reverse current (cataloged, not measured). If you don't have a 100-microampere meter, the 50-microampere *VU* meter, 5E3705, currently offered by Polypaks for just over $1, is most acceptable. Transformer T1 was salvaged from a junked, transistorized a-m broadcast receiver. Anything with a 1k - 10k input impedance and with a transformation of two to three times that impedance in the center-tapped secondary will do. If all else fails, and your junk box is as barren as Mother Hubbard's cupboard, a Triad A31X, Stancor TA31, or Allied interstage 6T14PC would be ideal.

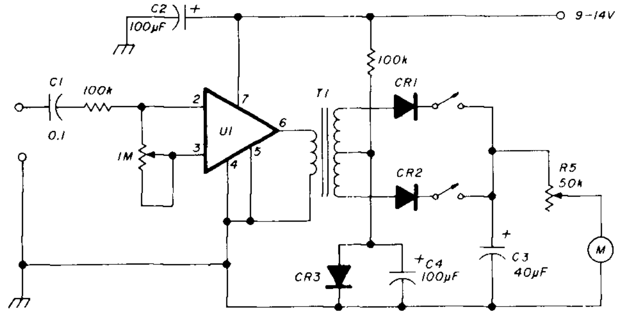
Referring to **fig. 4**, C1 is an input coupling capacitor for U1. Any value between 10 and 100 microfarads will do for capacitor C4; its function is to stabilize the voltage across CR3. The 40μF capacitor (C3), shunting pot R5, and the meter provide meter damping. The optimum value of C3 depends on the internal resistance of the meter and the magnitude of the calibration resistance. I tried several values between 10 and 200 microfarads before deciding that, for my setup, the 40-microfarad capacitor was adequate. The meter movement was damped but not to the point of being sluggish. It's a matter of personal preference.

precalibration notes

Before discussing meter calibration, I should comment on a possible need for temporary modification of the receiver. To reduce the consequences of thermally induced noise in the a-f amplifiers, it's customary to use frequency pre-emphasis and de-emphasis. The fm transmitter emphasizes the higher audio frequencies by shaping the amplifier-response curve. The receiver uses a de-emphasis circuit following the discriminator or detector to re-establish balanced levels.

To measure deviation the signal must be picked off ahead of the de-emphasis circuit. When discrete components are used, as in the circuit of **fig. 3A**, the deviation meter can be connected at point **A** with no circuit change.

If the receiver uses an IC for the detector, it will be necessary to defeat temporarily the de-emphasis circuit by lifting the ground side of a capacitor. If the IC



NOTES: UNLESS OTHERWISE SPECIFIED
1. ALL RESISTORS ARE 1/4 WATT.
2. CR1, CR2, CR3 ARE 1N459.
3. M1 IS 100μA (SEE TEXT).
4. T1 (SEE TEXT).
5. U1 IS LM380.

fig. 4. Schematic of a simple deviation meter discussed in the text. Component values are not critical.

is a type CA3065, MC1358, μA3065, ULN2165, C6063P, or SK3072, lift the ground side of the capacitor connected to pin 7 and connect the meter at pin 14. If it is a type CA2111A, MC1357P, C6062P, or SK3135, lift the ground side of the capacitor connected at pin 14 and pick up the signal on pin 1. For other chips consult the manufacturer's data or perhaps the receiver circuit diagram. Look for a capacitor in the range 0.005 - 0.1 microfarad from a pin to ground and not by-passing a resistor. I removed the 0.005-microfarad capacitor from the de-emphasis circuit in my Pace scanner and found that it made so little difference in the audio quality that it was never replaced.

meter calibration

Having ensured the readings will be free of de-emphasis effects, meter calibration is straightforward. The easiest way to do this is to use a digitally synthesized transmitter as a signal source.

First, disconnect the transmitting antenna and connect a suitable dummy load. Tune the transmitter and the receiver to be used with the deviation meter to the same frequency. Close the transmit switch *with no modulation present* and measure the dc voltage at the discriminator or detector output. Be sure to use a dc-coupled oscilloscope or a high-impedance voltmeter. If both rigs are tuned to frequency and the discriminator is properly balanced, there will be zero volts out. If some other voltage is sensed, find out why and correct it before proceding.

Next, shift the transmitter frequency up 5 kHz by using the PLUS 5 KHZ switch on the transmitter. Read and note the voltage at the discriminator output. It will be on the order of 1 volt. Now, leave the 5 KHZ switch alone but decrease the transmitter frequency 10 kHz. Voltage at the discriminator should be of the same magnitude but of opposite polarity to that previously measured. That is, if it was + 1 volt, it

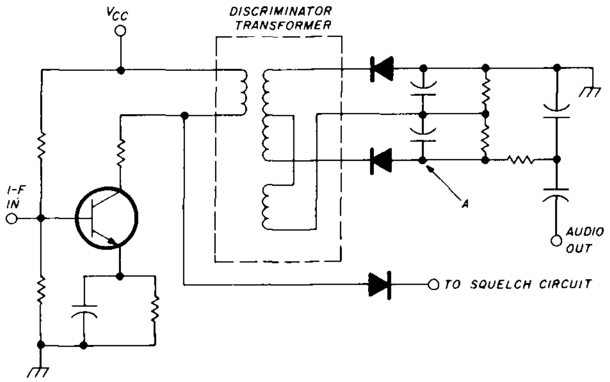


fig. 5. Typical fm discriminator using discrete components. The deviation meter can be connected at point A with no circuit changes. For circuits using ICs, see text.

should now be − 1 volt. If necessary, retrim the discriminator until positive and negative frequency offsets yield the *same* voltage amplitude at the discriminator output. Having achieved that, the receiver is known to be balanced, and the detector output for ± 5 kHz is known.

A decision is now in order. What is the desired full-scale reading for your deviation meter, and over what range is it to be linear? In the prototype unit I opted for, a 10-kHz full scale was necessary to have the desired 5 kHz at center scale. I chose, rather arbitrarily, to make the meter linear up to 7.5 kHz to allow for some padding beyond the region of primary interest. You may want to use some other numbers. Changes from the following procedure to yield numbers of your choice should be obvious.

meter linearity

Assuming the 7.5-kHz linear range is acceptable, set the output of an audio-frequency generator so that its peak-to-peak value is three times the previously measured 5-kHz deviation output voltage. (Note that for 10-kHz linearity, the p-p reading should be four times the reading previously measured.)

The frequency isn't critical. If nothing else is available, use a 60-Hz signal. A 1000 - 3000 Hz signal is preferred. Feed the signal to the deviation-meter input while observing the output waveform (pin 6 of the LM380) on your oscilloscope. Adjust the potentiometer connecting pins 2 and 3 of the IC for maximum signal output without limiting or other distortion. This establishes meter linearity.

Decrease the injected-signal amplitude until it's twice the 5-kHz deviation voltage. Again, this is peak-to-peak voltage. Adjust the meter series pot until the needle points where desired (center scale on the prototype). The deviation meter is now calibrated and can be used to set the deviation-limit level of the transmitter being adjusted.

calibration using a frequency counter

In the absence of a digitally synthesized transmitter, the deviation meter can be calibrated using an audio signal generator and a frequency counter. The technique involved derives from further application of **eq. 1**. At a modulation index of 2.4 there's no power in the carrier, all of it having been transferred to the sidebands. For a deviation of 5 kHz, a modulating frequency of 2080 Hz is necessary to get an MI of 2.4. *(5000/2080 = 2.4)*.

Set up a transmitter and the receiver to be used with the deviation meter on a common frequency, as before. This time, however, adjust the discriminator very slightly so that a dc voltage is measured in the presence of unmodulated rf. Now inject the 2080-Hz signal into the audio input of the transmitter. It can be audio coupled through the microphone or directly coupled, whichever is convenient. Increase the injected-signal amplitude from a very low level while observing the dc voltage at the discriminator output. This voltage will drop to zero when the injected-signal amplitude corresponds to a 5-kHz deviation. Holding the amplitude constant, drop the frequency to about 1000 Hz and tweak the series pot used for calibrating the meter until the latter indicates 5 kHz. Check pin 6 of the LM380 to make sure that the sine wave at that point isn't distorted. If it is, adjust the pot across pins 2 and 3 of that chip to remove the distortion, and readjust the meter calibrating resistor as necessary.

setting deviation

Excite the microphone with any loud, high-frequency tone — a loud sustained whistle is adequate. Adjust the deviation level control so that the deviation meter reads no more than 5 kHz. Talking into the microphone in normal tones should yield an average deviation of 2.5 kHz to 3.5 or 4 kHz — again depending on individual voice pitch. If it's much less than this, and if the rig has an audio gain control, try increasing the gain slightly. Recall, however, that the gain control was previously set at the upper level of the amplifier's linear range. Therefore a tradeoff between amplitude and amplitude linearity will have to be made.

If a *TOUCH TONE™* pad is used, the high tone group should cause a deviation meter reading of 4 - 4.5 kHz; for the low tone group, it should be about 3 kHz.

You've now properly set the average and maximum deviation on your fm transmitter. Stand by to pride yourself on the fact that your rig is giving you *maximum* talk power per watt input, and that you're one of the good guys when it comes to bandwidth conservation.

ham radio

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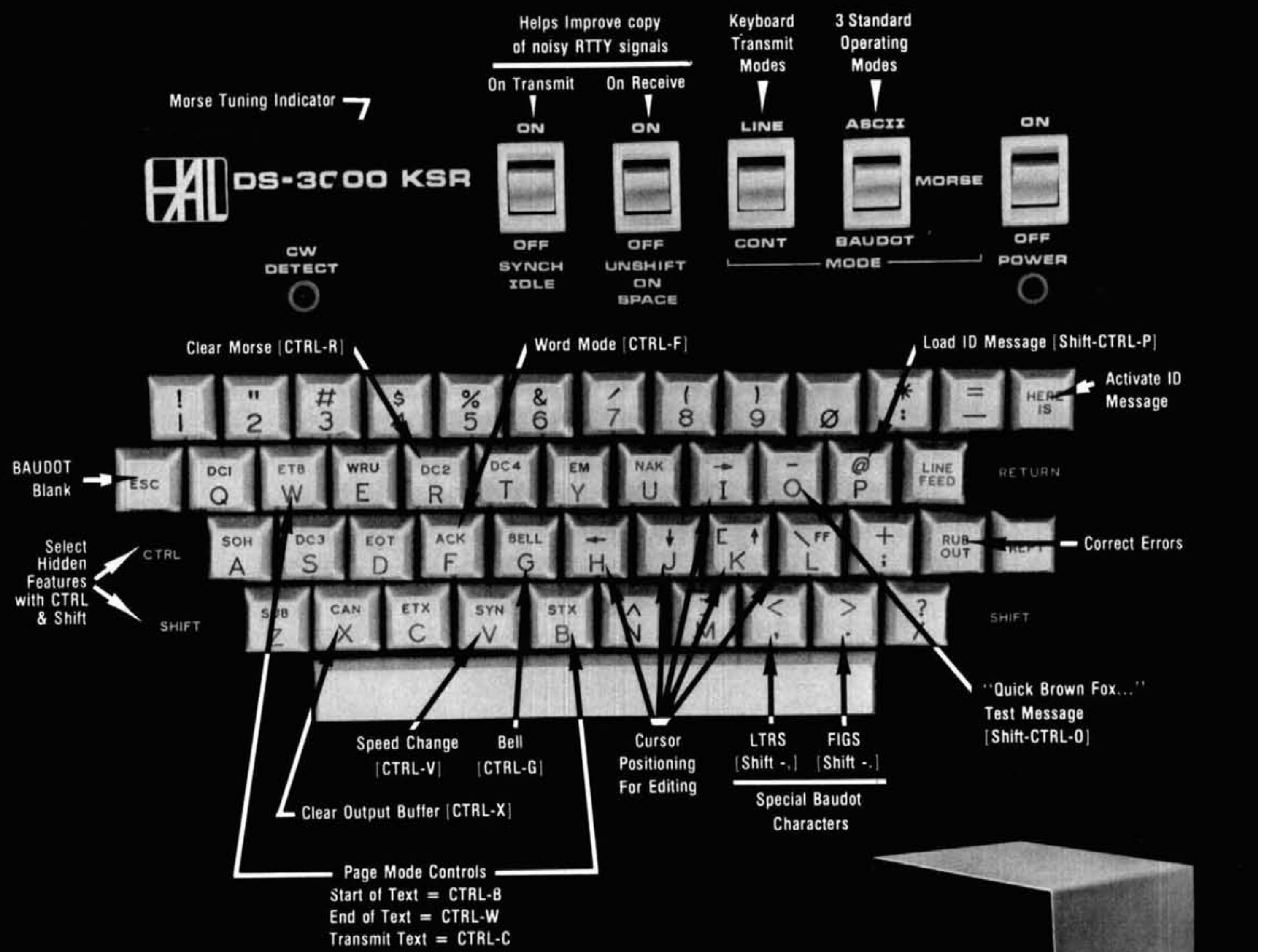

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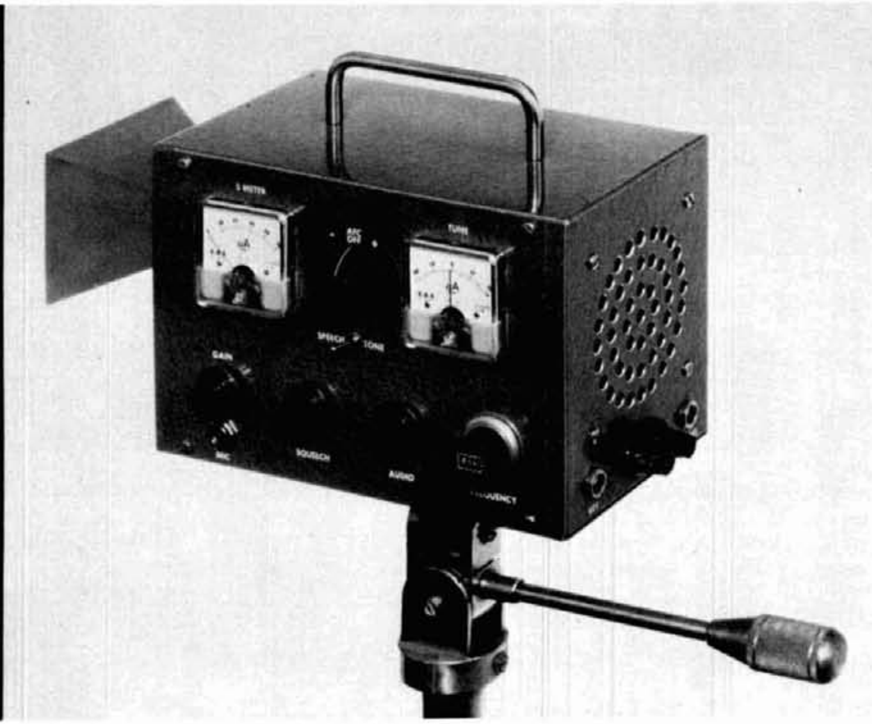

10-GHz Gunnplexer transceivers — construction and practice

Discussion of the various aspects of Gunnplexer transceiver construction and operation, including two practical transceiver designs

Microwave communications is one of the last frontiers of Amateur Radio; thanks to the Gunnplexer transceiver module offered by Microwave Associates, it's now easier than ever to put together a practical station for amateur operation on the 10-GHz band. Only a few years ago a "simple" microwave setup required a rack-full of equipment and friends in the industry who could provide hard-to-find parts. With the Gunnplexer, an entire microwave system can now be held in one hand. It can be easily backpacked to the highest mountain tops, and it can be operated from a single 12-volt battery.

As you receive it, the Gunnplexer module is not a complete transceiver; to put it on the air you need a dc power supply, a simple speech amplifier, and an fm receiver. You can put together a working system in one evening. To build a complete transceiver like that described in this article will take a little longer.

what is a gunnplexer?

The heart of the Gunnplexer is the Gunn diode oscillator, named after the IBM engineer who invented it in 1963, John Gunn. While measuring the resis-

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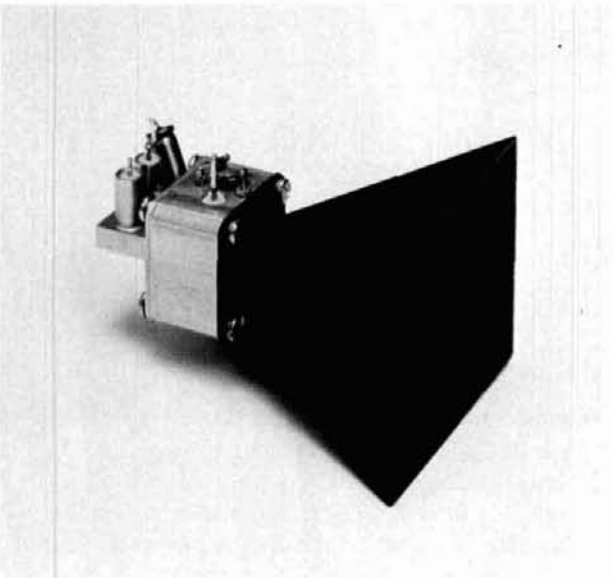
tance of gallium arsenide (GaAs), Gunn found that when the voltage across a thin wafer of the material was increased above a certain point, the current fluctuated at microwave frequencies. The mechanism which caused this was a mystery at first, but Gunn suspected a negative resistance due to electron movements within the gallium arsenide. This eventually proved to be the case (a detailed description of the Gunn diode phenomenon is contained in reference 1).

When a Gunn diode is placed in a resonant microwave cavity, small amounts of power can be obtained at the desired frequency. The cavity can be tuned mechanically, or a voltage-variable capacitor (varactor) may be used to change the resonant frequency of the cavity. The Gunnplexer (**fig. 1**) uses both a mechanical tuning screw and a varactor diode; frequency modulation is obtained by placing a small modulating voltage across the varactor. Power is coupled out of the cavity through an iris. The size of the iris must be determined experimentally for the best compromise between maximum power output and isolation from changes in diode impedance and load.

In the Gunnplexer the Gunn oscillator provides both the transmit power and the local-oscillator injection for the mixer diode. The ferrite circulator couples a small amount of energy into the low-noise Schottky mixer diode and isolates the transmit and receive functions. Since the Gunn oscillator functions as both the transmitter and receive local oscillator, the i-f receiver at each end of the communications link must be tuned to the same frequency, and the frequencies of the Gunn oscillators at each end of the link must be separated by the i-f.



Microwave Associates 10-GHz Gunnplexer.

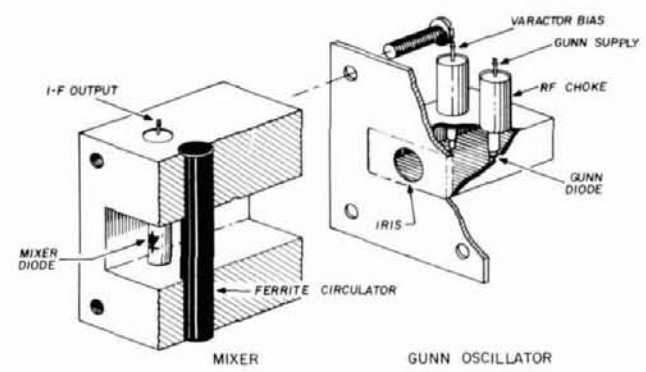


fig. 1. Cutaway view of the Microwave Associates Gunnplexer. The Gunn diode is mounted in a resonant cavity which is tuned by a tuning screw (coarse tuning) and a varactor (fine tuning). Microwave energy is coupled out of the cavity through an iris. The ferrite-rod circulator couples a small amount of rf energy into the Schottky mixer diode; the circulator also isolates the transmit and receive functions and allows full-duplex operation.

Confused? Take a look at **fig. 2**. Here Gunnplexer 1 is tuned to the center of the 10-GHz amateur band at 10250 MHz. If a 30-MHz i-f receiver is used, Gunnplexer 2 must be tuned either 30 MHz higher or lower than Gunnplexer 1. Assume it's tuned 30 MHz higher at 10280 MHz; its signal will mix with the 10250-MHz LO in Gunnplexer 1 to provide an output to the receiver at 30 MHz. Conversely, the 10250-MHz transmit signal from Gunnplexer 1 will mix with the 10280-MHz LO in Gunnplexer 2 to provide an output at 30 MHz.

gunnplexer communications range

One of the first and most asked questions about Gunnplexers is, what is their maximum range? Since most microwave communications systems are based on line-of-sight transmission, it's a relatively easy matter to determine the effective communications range of any Gunnplexer system. When the distance between the two stations is known, path loss in dB is given by:

$$92.5\ dB + 20 \log f\ (GHz) + 20 \log D\ (kilometers)$$

$$96.6\ dB + 20 \log f\ (GHz) + 20 \log D\ (miles)$$

where f is the operating frequency and D is the distance between transmitting sites. Note that each time the frequency is doubled, the path loss increases by 6 dB. This is shown graphically in **fig. 3**, which shows the path loss *vs* distance for each of the amateur bands above 1000 MHz. At 10250 MHz, the center of the 10-GHz amateur band, the path loss equation can be simplified to:

$$112.7 + 20 \log D\ (kilometers)$$

$$116.8 + 20 \log D\ (miles)$$

In other words, the path loss over a distance of 1 km is 112.7 dB; it increases 6 dB each time the path length is doubled. The objective is to build enough gain and sensitivity into the microwave system to overcome the loss over the desired path. This is a function of transmitter power, antenna gain, receiver sensitivity (noise figure), and receiver bandwidth, but it's not as complicated as it sounds because all these factors can be easily translated into dB.

The graph of **fig. 4** has been designed to simplify the calculation of communications range at 10250 MHz and is normalized to a power output of 15 mW, receiver bandwidth of 200 kHz, 12-dB noise figure, and 17-dB gain antennas at each end of the link. This is what I consider a minimal Gunnplexer system. The horizontal line labelled THRESHOLD is the beginning of reception of intelligible speech and allows no margin for fading due to rainfall, multipath propagation, or other environmental effects. With the minimal Gunnplexer system, threshold occurs at a distance of about 127 kiliometers (76 miles). Since a carrier-to-noise ratio of 8-10 dB is recommended for reliable communications, about one-third this distance could be used for successful communications.

There are four major things which can be done to increase range: use higher transmitter power, reduce receiver bandwidth, improve receiver sensitivity, or increase antenna gain. The effects of power output and receiver bandwidth are shown in the chart on **fig. 4**. Each improvement in system performance adds the stated number of dB to the carrier-to-noise ratio. A 40-mW Gunnplexer with a receiver bandwidth of 25 kHz, for example, improves the carrier-to-noise ratio by 13.3 dB (4.3 dB for 40 mW transmitter power, plus 9.0 dB for reduced bandwidth). This system would provide a carrier-to-noise ratio of 8 dB at a line-of-sight distance of 233 kilometers (145 miles).

When calculating the communications range of a microwave system, all the gain and loss components of the system must be considered, as shown in **fig. 5**. Here a distance of 50 km (30 miles) is assumed, so the path loss is 146.7 dB. The other item which is fixed is the thermal noise floor, at − 144 dBm, which is set by the laws of nature and determines the ultimate sensitivity of the receiver.[2]

Beginning at the transmitting end of the link, we have 15 mW power output (+ 11.8 dBm). To this is added the 17-dB gain of the antenna. When the path loss is subtracted, the signal level at the receiving site is − 117.9 dBm. The 17-dB-gain receiving antenna increases the signal to − 100.9 dBm. From this must be subtracted the 12-dB noise figure and the 200-kHz bandwidth factor (23 dB), for a signal level of − 135.9 dBm. The difference between this and the thermal noise floor at − 144 dBm is the carrier-to-noise ratio. For this link, + 8.1 dB.

The easiest way to improve range is to use a higher

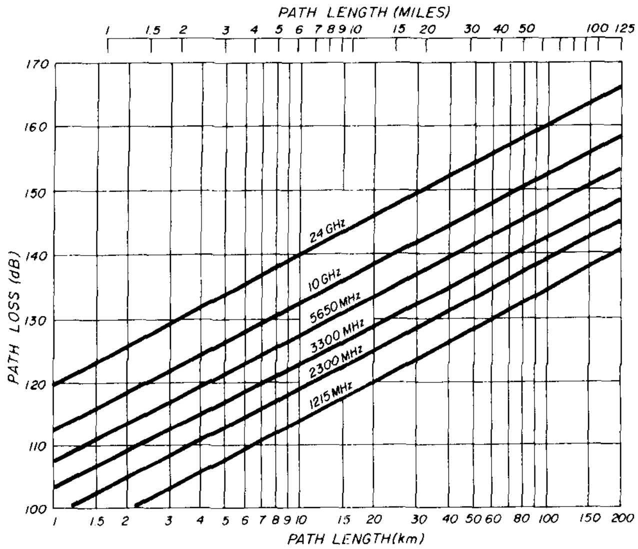


fig. 3. Path loss vs distance for each of the six amateur microwave bands. Note that path loss increases 6 dB each time the frequency or path length is doubled. Loss over a 61.7-km path at 1215 MHz, for example, is 130 dB; at twice the frequency (2430 MHz) the loss is 6 dB greater; at 8 times the frequency, near the 10 GHz band, loss is more than 18 dB greater. This graph assumes line of sight with no obstructions of any kind.

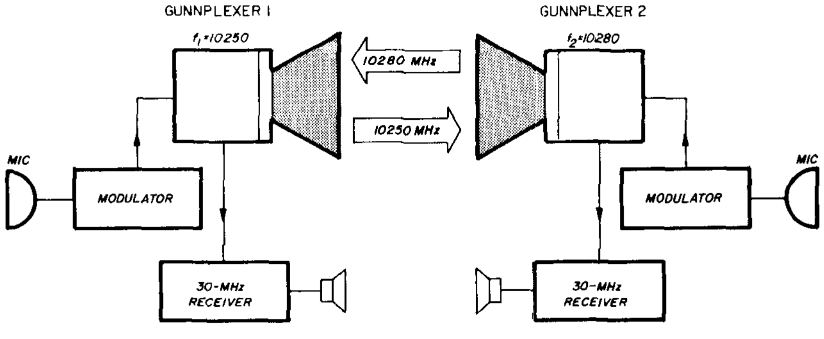


fig. 2. Gunnplexer operation. Since the same oscillator is used as both a transmitter and local oscillator for the mixer, the i-f at each end of the link must be at the same frequency, and the Gunn oscillator frequencies must be separated by the i-f. In the example shown here, Gunnplexer 1 is tuned to 10250 MHz; 30-MHz receivers are used, so Gunnplexer 2 at the other end of the link must be tuned either exactly 30 MHz higher or lower (to 10280 or 10220 MHz).

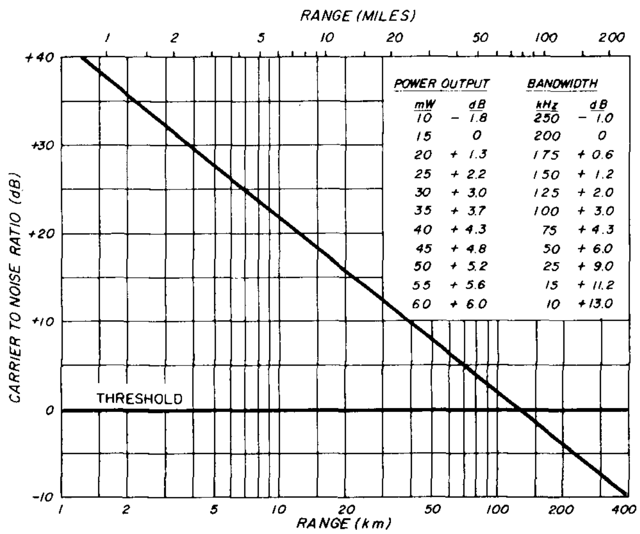


fig. 4. Carrier-to-noise ratio vs distance for two 15-mW Gunnplexers at 10250 MHz, equipped with 17-dB-gain horn antennas; receiver noise figure is assumed to be 12 dB with 200 kHz bandwidth. The THRESHOLD line is the beginning of the reception of intelligence. At a distance of 127 km (76 miles) the carrier is at the noise level or threshold; at a distance of about 40 km (25 miles) the carrier-to-noise ratio is 10 dB, the minimum signal level recommended for reliable voice communications. Range can be lengthened by increasing transmit power, decreasing bandwidth, or adding antenna gain (see text). Improvements in dB for increased output and narrower bandwidth are shown.

gain antenna. Unlike the lower frequencies, where antenna gain is hard to come by, on the microwave bands it's relatively easy. A 24-inch (61-cm) parabolic reflector, for example, yields 32 dBi gain. If used at only one end of the system shown in **fig. 5**, this would have the effect of increasing the range to

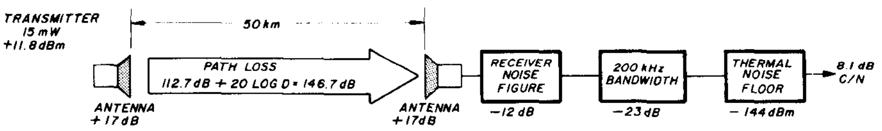


fig. 5. Example of a path-loss calculation at 10250 MHz. With two 15-mW Gunnplexers equipped with 17-dB gain antennas, and 12-dB noise figure in 200-kHz bandwidth, the carrier-to-noise ratio at 50 km is 8.1 dB.

Transmitter power, 15 mW	+ 11.8 dBm	+ 11.8 dBm
Add transmitter antenna gain	+ 17.0 dBi	+ 28.8 dBm
Subtract path loss	+ 146.7 dB	− 117.9 dBm
Add receiver antenna gain	+ 17.0 dBi	− 100.9 dBm
Subtract receiver noise figure	− 12.0 dB	− 112.9 dBm
Subtract 200 kHz bandwidth factor	− 23.0 dB	− 135.9 dBm
Thermal noise floor		− 144.0 dBm
	Carrier-to-noise ratio:	+ 8.1 dB

nearly 2000 km (1200 miles) for the same 8.1 dB carrier-to-noise level! That's obviously well beyond line-of-sight for any two earth-based locations. One disadvantage of high antenna gain is antenna alignment; the 4-degree beamwidth of a 24-inch dish leaves little room for error when pointing the antenna at another station.

You can also increase range by reducing the bandwidth of your receiving system, but because of the thermal drift of the Gunnplexer, this requires a system which phase locks the Gunn oscillator to a crystal-controlled reference oscillator. The cost of a phase-locked system is somewhat less than that of a commercial parabolic reflector, but system gain is only on the order of 12-13 dB when compared with a system with 200-kHz receiving bandwidth. On the other hand, a phase-locked system permits the use of CW, which provides reliable communications with lower carrier-to-noise ratios than voice, so there may be the equivalent of an additional 4-5 dB gain available.

For greater range you can also increase transmitter output or improve receiver noise figure, but both are expensive and limited to a certain extent by the present state of the art.

gunnplexer performance

The Gunnplexer performance measurements discussed here were made by B. Chambers, G8AGN, of the Department of Electronic and Electrical Engineering at the University of Sheffield, England, who is also a member of the Microwave Committee of the Radio Society of Great Britain. Front-end performance was not measured because, in practice, receiver sensitivity and noise figure are highly dependent on the operator's choice of i-f strip and the degree of matching between the mixer diode and the i-f preamplifier. Therefore G8AGN made measurements only to check the performance of the Gunn oscillator.

When a variable voltage was connected to the Gunn diode, it was found that rf power was produced with an applied voltage as low as 5 volts. Most of the tests, however, were accomplished with + 10 volts applied to the Gunn diode and + 4 volts bias on the varactor diode.

Using a Systron-Donner model 6057 frequency counter with an upper frequency limit of 18 GHz, G8AGN found that the Gunn oscillator drifted down in frequency by about 3 MHz during the initial one-hour warm-up period. A further frequency check 15

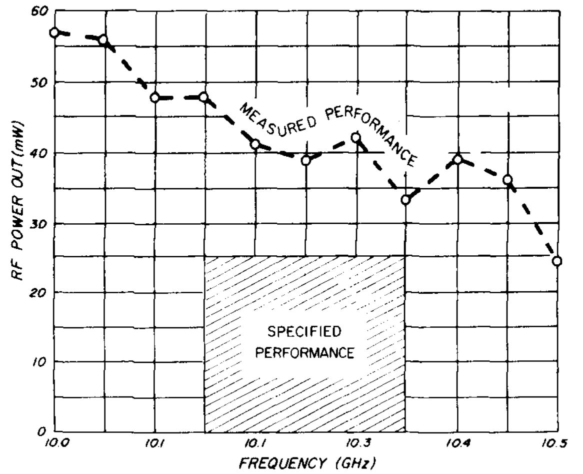


fig. 6. Typical variation of Gunnplexer output power as the frequency is tuned mechanically through the 10-GHz amateur band, as measured by G8AGN. At all frequencies the output was well above the rated 25 mW.

minutes later showed that the oscillator was drifting down in frequency by about 28 kHz per minute. This rate of drift is quite acceptable in practice unless a narrow-band system is being used and there is no provision for AFC.

The mechanical tuning range of the oscillator was checked next and found to extend from 9641 MHz up to 10764 MHz. The rf power output over this frequency range was measured with a Marconi model 6460 power meter with a coaxial head, buffered by a fixed 20-dB pad. This was preceded by a coax-to-waveguide transition and slide-screw tuner which was adjusted before each reading to ensure that the oscillator was delivering power into a matched load. **Fig. 6** shows the variation of rf output power over the frequency range from 10.0-10.5 GHz. Rf power measurements at the extremities of the tuning range showed 39 mW at 9641 MHz and 24 mW at 10764 MHz.

For a given setting of the mechanical tuning screw, the frequency of the Gunn oscillator may be tuned electrically by changing the voltage applied to either the Gunn diode or the varactor. Varying the voltage of the Gunn diode over the range from +5 to +11 volts produced a frequency change of 13.3 MHz about a preset value of 10250 MHz. This represents approximately 2.2 MHz per volt for frequency pushing and is well within the quoted specification.

With the Gunn diode held at +10 volts, the varactor bias was varied from +1 to +12 volts and measurements were made of both frequency and rf power output. Although up to +20 volts bias may be used on the varactor, measurements were made only to +12 volts because this is the maximum voltage usually available for portable operation. **Fig. 7** shows the result of these measurements. It can be seen that the maximum electronic tuning range was approximately 100 MHz, and that over this range the rf power output varied by about 3.5 dB.

The final set of Gunnplexer measurements made by G8AGN were concerned with the frequency-pulling performance of the Gunn oscillator. To make these measurements, the Gunnplexer was set up to deliver power to a load consisting of an adjustable short circuit; therefore, by varying the axial position of the short-circuit plane within the waveguide, a wide range of load impedances would be seen by the oscillator. For an axial variation of the short-circuit plane of 20 mm (0.8 inch), corresponding to a distance just greater than $\lambda_2/2$ at 10250 MHz, the total frequency variation was found to be 12 MHz.

The result of this test suggested that the ferrite circulator should be "transparent" enough for the Gunnplexer to be frequency locked using a cavity wavemeter, and this, in fact, proved to be the case. A TE_{011} mode transmission-type cavity wavemeter with a quoted Q factor of 8000 was available. This was simply bolted to the Gunnplexer assembly — the resulting separation between the wavemeter and the coupling iris to the Gunn oscillator being about 6.5 cm (2.6 inches). The wavemeter cavity had provision for attaching a waveguide diode holder, and this was

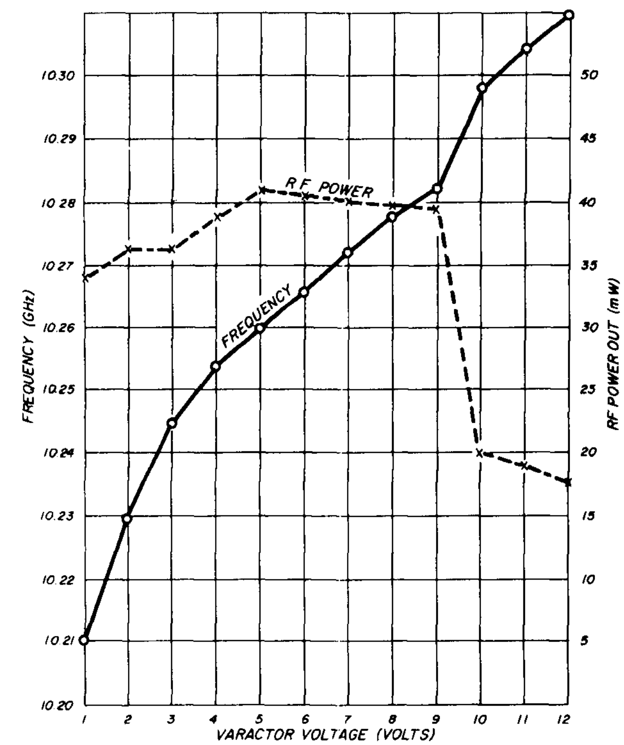


fig. 7. Frequency variation and measured power output with changes in varactor bias, as measured by G8AGN. Power output varies less than 3.5 dB over the nearly 100-MHz tuning range.

used in conjunction with a sensitive milliammeter to detect when the cavity was tuned near resonance.

With a little practice, G8AGN found that it was possible to hold the frequency of the Gunn oscillator to within 1 kHz for periods of minutes at a time. In view of this, it seems probable that the Gunnplexer could also be injection locked using a crystal controlled source, although this was not tried.

power supply

The first requirement for a Gunnplexer system is a regulated +10 volt power supply. Unfortunately, there aren't any readily available, high-current, three-terminal IC regulators with a 10-volt output (the Lambda LAS1510 meets these requirements, but is difficult to purchase in small quantities).* The answer is the Fairchild μA78MG 4-terminal regulator, which requires only two external resistors to set the regulated output voltage (see **fig. 8**). This regulator will provide in excess of 500 mA output, so it's adequate for most Gunnplexer systems.

For precise voltage adjustments, I have included a miniature 500-ohm pot between the two 4700-ohm resistors; this allows the output voltage to be set within a few millivolts of +10 volts. If you're not this fussy, you can connect the IC's control terminal (pin 4) directly to the junction of two 4700-ohm resistors — the output voltage should be within 5 per cent of the required 10 volts. This is probably close enough for most applications.

In many circuits using the μA78MG regulator the bypass capacitors may not be required. However, for stable operation of the regulator IC over all voltage and current input ranges, bypassing is recommended by the manufacturer (0.33 μF at the input and 0.1 μF at the output). The input bypass is necessary if the regulator is located far from the filter capacitor in the power supply; bypassing the output improves the transient response of the regulator.

tuning range

The frequency of the Gunnplexer is controlled by

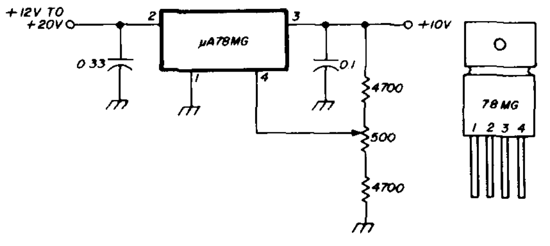


fig. 8. Regulated Gunnplexer power supply can be adjusted to exactly +10 volts; with proper heatsinking, this circuit will provide current in excess of 500 mA. The 0.33-μF capacitor at the input and 0.1 μF at the output improve circuit performance.

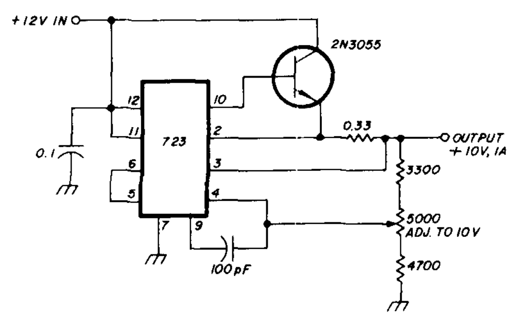


fig. 9. Simple +10 volt regulator using readily available parts, designed by W1SL, will supply up to 1 ampere. The 723 regulator is available from Radio Shack (part number 276-1740) as is the 2N3055 transistor (Radio Shack 276-1634).

the voltage on the built-in tuning varactor, the setting of the mechanical tuning screw, and the supply voltage to the Gunn diode. Unless otherwise specified, the Gunnplexer is mechanically tuned to 10250 MHz at the factory with 10.0 volts on the Gunn diode and 4.0 volts across the varactor. The output frequency of the Gunnplexer can be adjusted ±100 MHz with the tuning screw, but I don't recommend touching the mechanical tuner unless you have access to a microwave frequency counter; you will find it difficult to accurately retune the unit to 10250, the center of most amateur activity on this band.

The Gunnplexer can also be electronically tuned by varying the voltage across the varactor from 1 to 20 volts; this is the preferred method, and a tuning range of 60 MHz is guaranteed. Electronic tuning range varies from unit to unit, but data is furnished with each Gunnplexer so you can easily estimate frequency output *vs* varactor voltage. Many units have an electronic tuning range of 100 MHz or more, so it's not necessary to touch the mechanical tuning screw for most amateur applications.

Shown in **fig. 10** is a plot of frequency output *vs* varactor tuning voltage for a 40-mW Gunnplexer that I am using at my station. The tuning curve is quite nonlinear, with the greatest frequency change — 50 MHz — occurring as the varactor voltage is increased from 1 volt to 4 volts. An increase from 4 volts to 10 volts moves the output frequency up 40 MHz, and a change from 10 volts to 20 volts increases the output frequency 46 MHz. The total frequency change is 136 MHz. The tuning range of other Gunnplexers won't exactly follow this curve, but it gives you an idea of what you can expect.

The varactor also provides a way of frequency modulating the unit. If a small modulating voltage is

*Shortly after this article was written, Fairchild Semiconductor announced the μA78C00 series of 3-terminal voltage regulators which have rated output current greater than 500 mA. A 10-volt regulator, the μA78C10C, is included in the series.

impressed on the varactor bias, the frequency will be varied at an audio (or video) rate. Because of the wide electronic tuning range, the required modulation voltage is very small; 10 mV or so for 75 kHz deviation, or less than 1 mV for 5 kHz deviation. However, don't plan on using narrowband deviation unless you have a crystal-controlled, phase-locked system for stabilizing the Gunnplexer frequency.

The output frequency also varies with changes in the Gunn diode supply voltage — 15 MHz per volt maximum — but this isn't recommended as a tuning method. In addition, the power output and efficiency of the Gunnplexer has been optimized for a 10.0-volt supply, and you don't want to risk damaging the expensive Gunn diode.

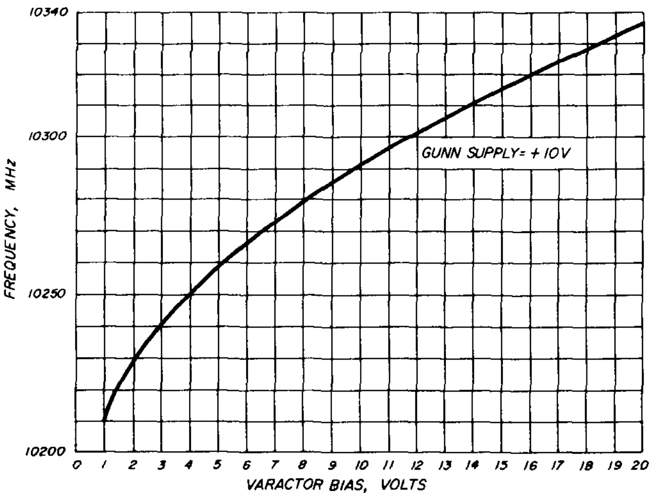


fig. 10. Output frequency vs varactor bias for a 40-mW Gunnplexer used by W1HR. The tuning range of other Gunnplexers won't exactly follow this curve, but can be estimated from the data furnished by Microwave Associates with each Gunnplexer.

In portable systems designed to operate from +12 volts, it's convenient to set the maximum varactor voltage at the +10-volt Gunn diode supply. This provides more than enough tuning range if you use a 30-MHz i-f system. Amateurs in Europe usually transmit voice on 10250 MHz and receive on 10280 or 10220; in the United States many stations have standardized 10250 for transmitting and 10280 for receiving (for full duplex operation one station transmits on 10250 and the other transmits on 10280).

If you use fm broadcast receivers at each end of the link with a 10-volt varactor supply, you may not be able to obtain sufficient tuning range to cover the required 100 MHz. However, if you use an auxiliary varactor supply that will provide up to 20 volts, you should have no difficulty obtaining the required range. In many cases the nominal 12 volts available

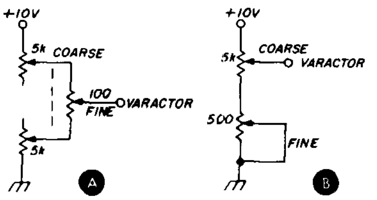


fig. 11. If a multi-turn potentiometer is unavailable, varactor bias can be controlled by one of the methods shown here. The resolution of the circuit at (A) is about four times better than with a 10-turn pot; the circuit at (B) has somewhat less resolution but is less expensive.

from an automobile battery will be sufficient. If you use an ac-powered dc supply for the varactor, however, be sure it's well regulated and filtered. Any ripple on the supply line will result in hum modulation.

varactor bias control

Since small changes in varactor bias have a large effect on the output frequency, a multi-turn potentiometer should be used for the tuning control (with a conventional 270° pot, the frequency can change 300 kHz or more for each 1 degree rotation of the pot's shaft). Sometimes you can find precision 10-turn pots on the surplus market, but, if not, there are several alternatives. One is to use a single-turn pot with a reduction unit like the Jackson Brothers 6:1 planetary drive. This may not be completely satisfactory, however, because resolution may be limited by man-

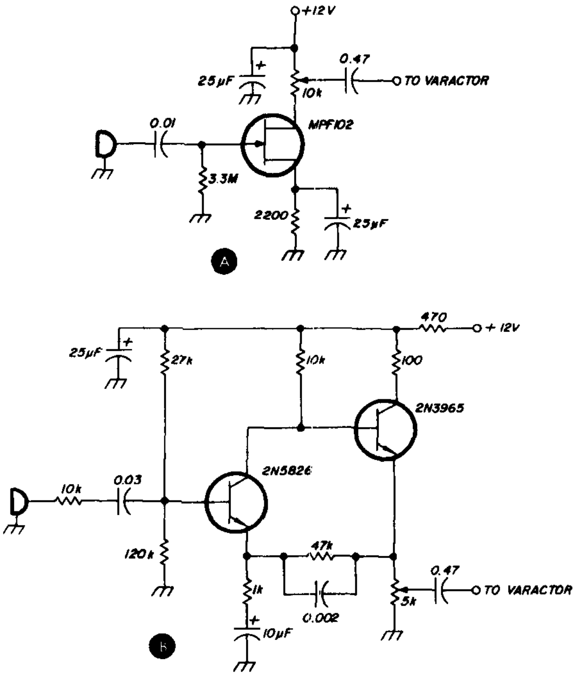
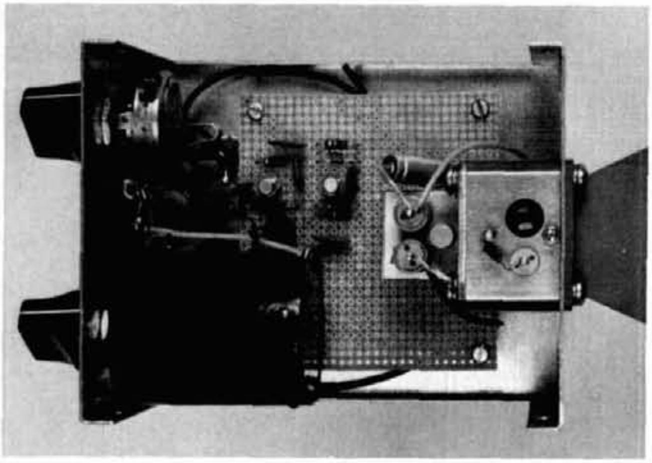
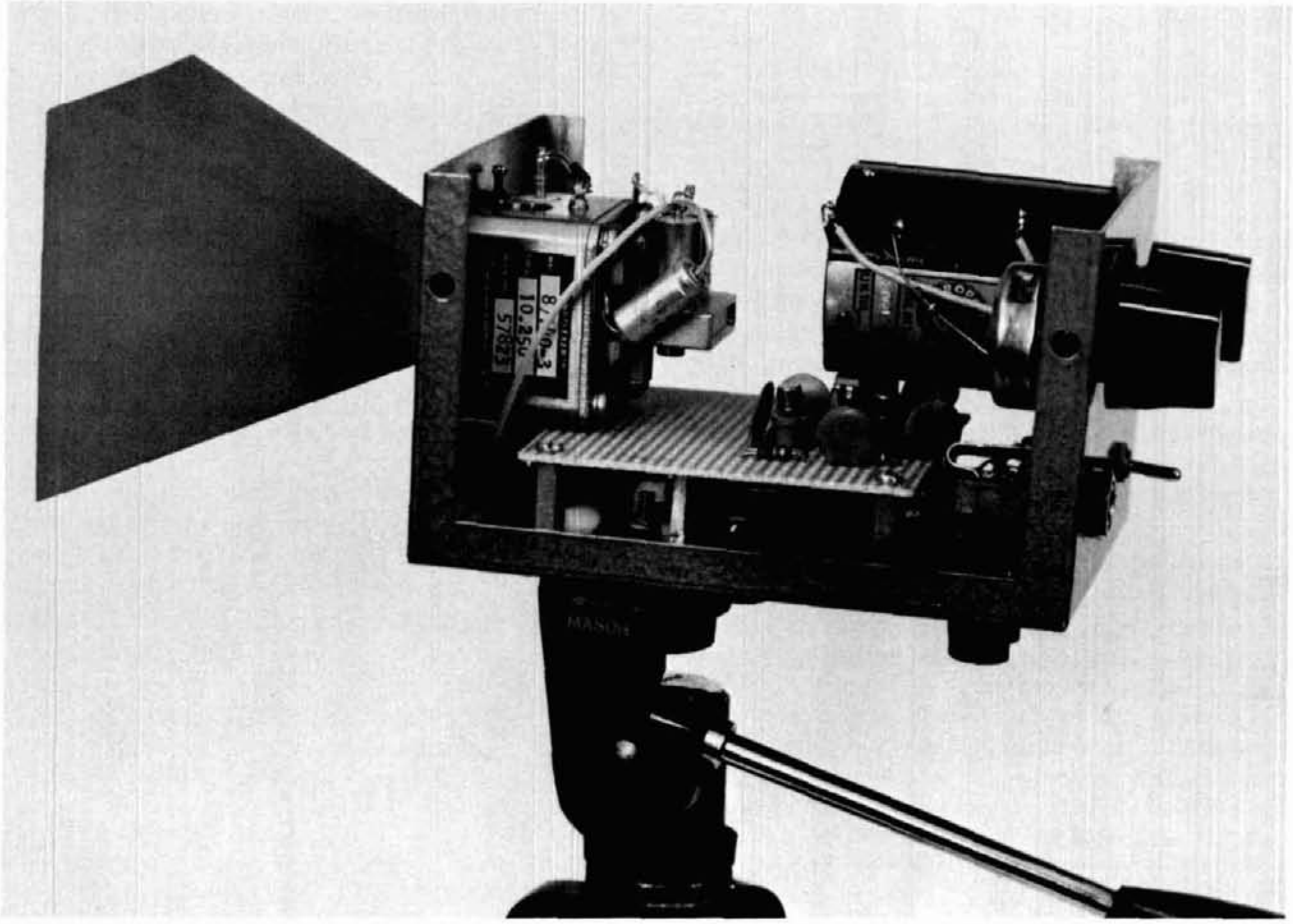


fig. 12. Two simple speech amplifiers which are suitable for use with Gunnplexers. The two-transistor circuit at (B) includes limited filtering for shaping audio bandwidth.





Minimal Gunnplexer system used by W1HR includes a 10-volt IC voltage regulator, simple speech amplifier, and tone oscillator. A phono connector on the bottom of the chassis is provided for the fm receiver. A 10-turn precision potentiometer found on the surplus market is used for frequency control.

*ufacturing tolerances in the potentiometer's resis-*tance element.

Two other possibilities for varactor control are shown in **fig. 11**. The system in **fig. 11A** uses one dual potentiometer for coarse adjustments and a *single-turn* pot for fine tuning. Resolution of this sys*tem is about four times better* than with a 10-turn pot and is suitable for the most demanding requirements. The bias control arrangement in **fig. 11B** does not provide as much resolution but is more economical. A disadvantage is that the resolution of the fine adjustment varies, and depends upon the setting of the coarse control; when the coarse potentiometer is in the center of its range, resolution approximates that of a 10-turn pot.

speech amplifiers

Because of the high sensitivity of the varactor, a very small modulation voltage (on the order of 10 mV p-p) is required to obtain 75-kHz deviation for wideband frequency modulation of the Gunnplexer; this greatly simplifies the design of a suitable speech

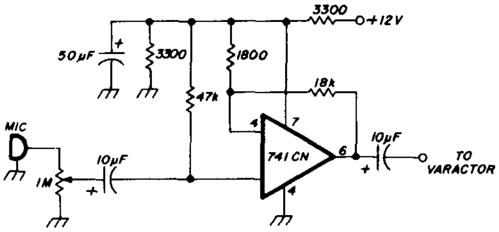


fig. 13. Speech amplifier circuit designed by G8AGN for Gunnplexer operation uses a low-cost 741 op amp and offers high input impedance.

amplifier. In its simplest form, the Gunnplexer speech amplifier requires only one transistor, as shown in **fig. 12A**. In this circuit the MPF102 fet exhibits high input impedance for a crystal, ceramic, or dynamic microphone, and provides more than enough voltage gain for full 75-kHz deviation at 10.25 GHz. Deviation is adjusted with the 10k potentiometer in the drain circuit.

The two-transistor speech amplifier in **fig. 12B** has an input impedance of about 20 kilohms and includes filtering to limit the speech bandwidth. For those who prefer to use ICs the circuit in **fig. 13** is recom-

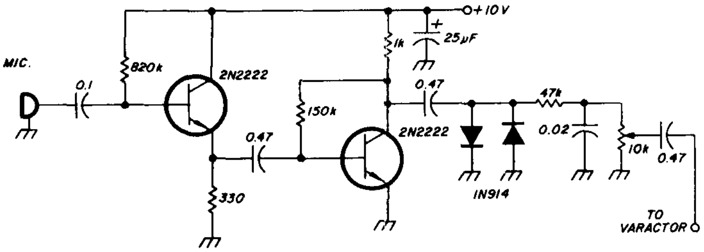


fig. 14. Two-transistor speech amplifier for Gunnplexers features high input impedance, good gain, clipping for improved audio punch, and a lowpass filter for limited audio bandwidth.

mended. This 741 speech amplifier was designed by G8AGN/G8CZO for use with a Gunn diode transmitter.[3]

In any frequency-modulation system the speech amplifier should, in addition to providing audio gain, include some form of speech processing to limit dynamic range so the audio signal doesn't exceed the maximum frequency deviation. This can be done with audio compression or by using a simple diode clipper to limit the audio peaks. The two-stage speech amplifier shown in **fig. 14** includes a clipper and lowpass RC filter (47k resistor and 0.02-μF capacitor) to reduce the harmonics produced by clipping. I used 2N2222 transistors in this circuit because I had them in my junk box, but most high-gain NPN transistors should work. If you wish, the same diode clipper and RC filter can be added to the circuits of **figs. 12** and **13**.

For most effective fm communications, the speech system should include a system for limiting bandwidth to 300-3000 Hz, and de-emphasis to correct the speech frequency characteristic. A circuit which

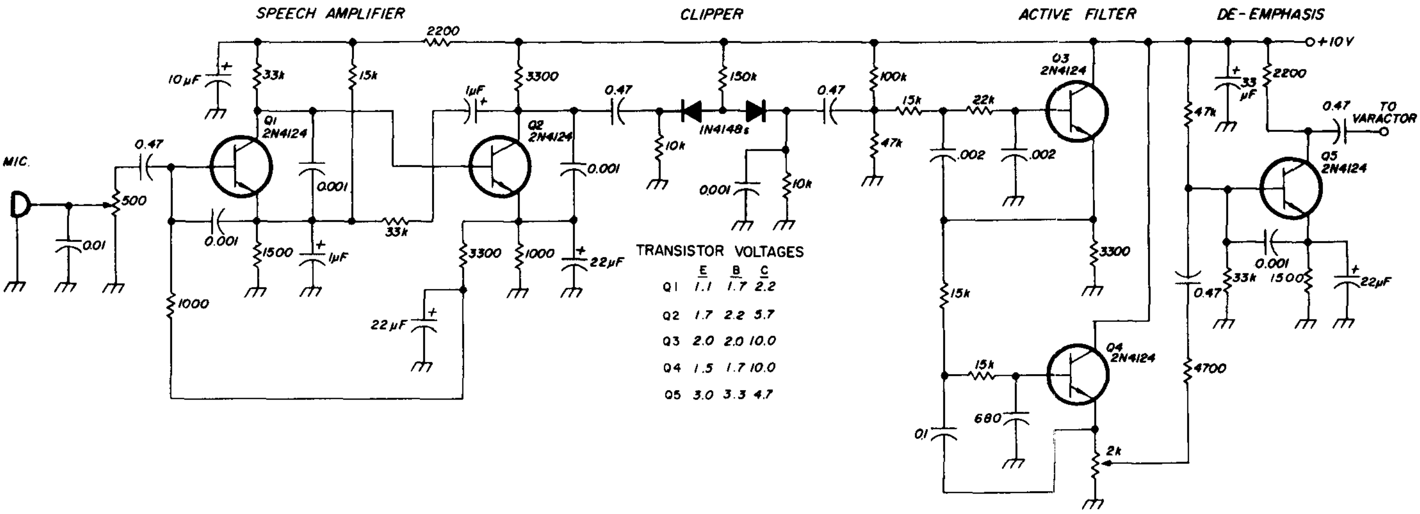


fig. 15. High-performance fm speech amplifier uses heavy feedback for reduced audio distortion. It also includes an audio clipper, 300-3000 Hz active audio filter, and de-emphasis stage. Both input and output controls are provided. Circuit board for this circuit is shown in fig. 22.

has a complete speech amplifier, clipper, active filter, and de-emphasis stage is shown in **fig. 15.**[4] The first two stages use heavy feedback to reduce distortion and improve frequency response. These stages are followed by a double-diode clipper and a two-stage active filter that has a 500-3000 Hz passband. The last stage provides de-emphasis. This amplifier gives an output of 100 mV for an input of 2 mV across 300 ohms; both input and output controls are provided. I have used this amplifier with good success at one end of a wideband Gunnplexer link.

tone oscillator

When lining up two Gunnplexer systems, particularly if you're using high-gain parabolic reflectors, it's helpful to continuously tone modulate your transmitter. There are several ways to generate an audio tone, but for minimum parts count I prefer the circuit of **fig. 16**, which uses a 555 timer IC. Total current drain with a 10-volt supply is only 10 mA. The 1-kHz squarewave output swings from ground to +10 volts; this is reduced to manageable levels for Gunnplexer use with the series 100k resistor and 200-ohm pot. The 10k resistor and 0.1-μF capacitor form a lowpass filter; in some applications the filter may not be required.

If you have a memory keyer, it can be plugged into the key jack and used to send your call sign, a series of vees, or your location. If you wish to send only your call sign, you might consider the automatic CW ID unit manufactured by Autocode.* Although this unit was designed for automatically sending CW identification for RTTY or vhf-fm transmissions, it is ideal for Gunnplexer systems.

i-f receiver

Although a 30-MHz i-f receiver is recommended if you want to work reliably over long distances, to get started with a Gunnplexer system many amateurs have used low-cost fm broadcast receivers tuned around 100 MHz. One popular unit is the Audiovox fm converter; this receiver sells for less than $20, can be completely converted to Gunnplexer use in one evening, and is a good compromise unit for getting started on 10 GHz with Gunnplexers. Complete conversion information is available from G. R. Whitehouse & Company.† The main disadvantage of an fm broadcast receiver is i-f feedthrough. For best results you must pick a frequency that is clear of local fm broadcasters. If you take this system mountain-topping, your problems with i-f feedthrough will increase dramatically, but it is still a good way to get started. Also, it's a simple matter to add a better receiver to your system later — no other parts of the set-up will have to be changed.

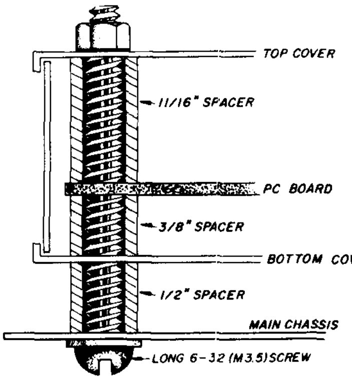


fig. 17. Method of mounting the DJ700 fm receiver with spacers and a long 6-32 (M3.5) screw. Similar mounting arrangements are used at the four corners of the fm receiver PC board.

Another low-cost approach to the i-f receiver can be found in the used two-way equipment market. Many of the fire, police, and public-service fm receivers built 10 or more years ago can now be purchased for a few dollars. The receiver you want for Gunnplexer use was originally designed to tune from 30 to 50 MHz and is built for wideband fm. Many of the newer fm receivers for this band are for narrowband fm, so they are not suitable for Gunnplexer use. A number of companies marketed solid-state receivers of this type in the 1960s, including Lafayette, Radio Shack, and Regency. Some had provisions for crystal control; this, if you can find one, is the type most suited to Gunnplexer communications. Price for a receiver of this type is typically around $5; most users have switched to more portable narrow-band receivers with scanners, so the older, tunable receivers have practically no commercial value.

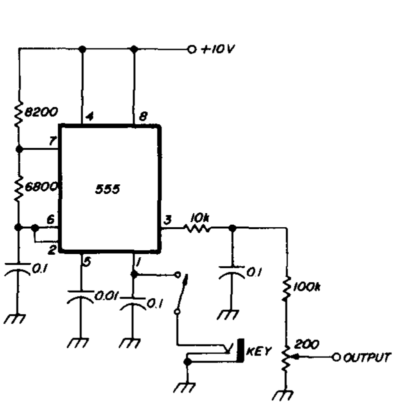


fig. 16. A 1000-Hz tone oscillator is very helpful when setting up a Gunnplexer link. It can also be used for MCW under weak-signal conditions.

*Autocode, 8116 Glider Avenue, Dept. H, Los Angeles, California 90045.

†G. R. Whitehouse stocks 15-, 25-, and 40-mW Gunnplexers; his address is Newbury Drive, Amherst, New Hampshire 03031.

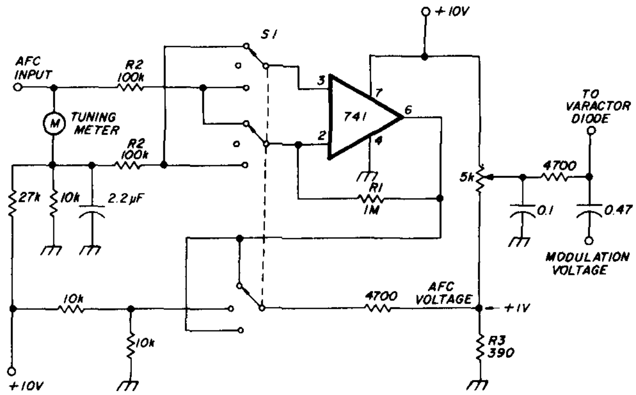


fig. 18. Gunnplexer AFC system designed by DJ7OO for use with his 30-MHz fm receiver. Circuit may be adapted to other fm receivers by changing the ratio of resistors R1 and R2. It may be desirable in some cases to replace R3 with a trimmer pot. In the center position of switch S1, the AFC is turned off, the two outer positions provide positive- and negative-going AFC voltage with increasing frequency (see text).

The choice of 30 MHz for the i-f receiver means that you can set up your Gunnplexer on 10250 MHz and tune in stations either 30 MHz above or below your center frequency. Many Gunnplexers don't have sufficient electronic tuning range to handle an i-f at 100 MHz with only +10 volts of varactor bias. If you have a +20 volt bias supply available, many Gunnplexers will tune the required 100 MHz, but that precludes most portable operation unless you provide additional batteries for the bias supply. For reasons mentioned previously, I don't recommend touching the mechanical tuning screw.

I have used both tunable and crystal-controlled 30-MHz i-f receivers in Gunnplexer links, and the difference is like night and day. Tunable receivers are fine if you're interested only in working over short distances, but if you want to communicate farther than you can shout, you have to use a crystal-controlled i-f receiver. Remember that the local oscillator for your receiver is the Gunn oscillator at the other station; for communications, the receivers at both ends of the link must be tuned to *exactly* the same frequency. Even at 30 MHz, a tunable receiver that is off frequency by only 1 per cent will be completely out of the passband of a wideband fm signal.

Automatic Frequency Control (AFC) is helpful when you first turn on your Gunnplexer, but if both stations are operating in essentially the same environment, I've found that frequency drift during warm-up is slow enough that it's an easy matter to keep the other station tuned in. Once the two Gunnplexers have reached thermal equilibrium, they'll sit on frequency for hours at a time.

The receiver I'm using in my Gunnplexer station was described by DJ7OO.[5] In addition to being crystal controlled, it has built-in provisions for a tuning meter *and* signal strength meter; both are extremely useful in setting up Gunnplexer links over marginal paths. Also, the output from the discriminator is available for AFC purposes. If you're interested in serious microwave communications, I highly recommend this receiver.

As supplied, the DJ7OO receiver is built into a tin-plated enclosure with no mounting tabs. If you wish, small L-shaped brackets could be soldered to the enclosure, or the receiver could be clamped into place. In my Gunnplexer transceiver I mounted the DJ7OO receiver with spacers and long screws; this seems to be more rugged than brackets or clamps, and, since the transceiver is designed for portable use, I wanted something that would stand up to unintentional abuse (see **fig. 17**).

If you purchase a DJ7OO i-f receiver, the only problem you may have is obtaining knobs to fit the potentiometer shafts. The diameter of these shafts is 4 mm — too large for 1/8 inch shafts, and too small for 1/4 inch! The best solution is to purchase knobs for 1/8 inch shafts and drill them out with a no. 22 or 4 mm drill. You can also wind tape around the shafts to build them up to 1/4 inch, but the knob will tend to feel sloppy and will probably be eccentric.

automatic frequency control

After a Gunnplexer is initially turned on, its output frequency drifts rapidly as the unit warms up. The typical drift rate is about 300 kHz per degree Celsius, and since the Gunnplexer temperature may go up 10 degrees per minute after it's first turned on, total frequency drift is 3 MHz or more. As the unit reaches thermal equilibrium, however, frequency drift slows, and, if the unit is shielded from wind currents, the output frequency is quite stable. If the Gunnplexers at opposite ends of a wideband fm communications link ($\Delta f = 200$ *kHz*) are in similar environments, they can be used for voice communications over long periods of time without any frequency adjustments.

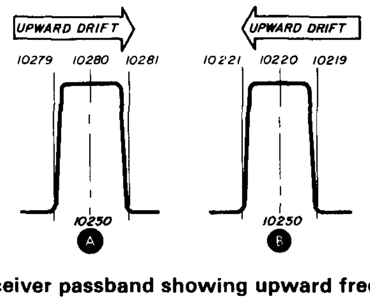


fig. 19. Receiver passband showing upward frequency drift of Gunnplexers operating above (A) and below (B) a Gunnplexer with AFC. To maintain the received signal in the center of the passband requires AFC with *positive* sense in (A) and *negative* sense in (B).

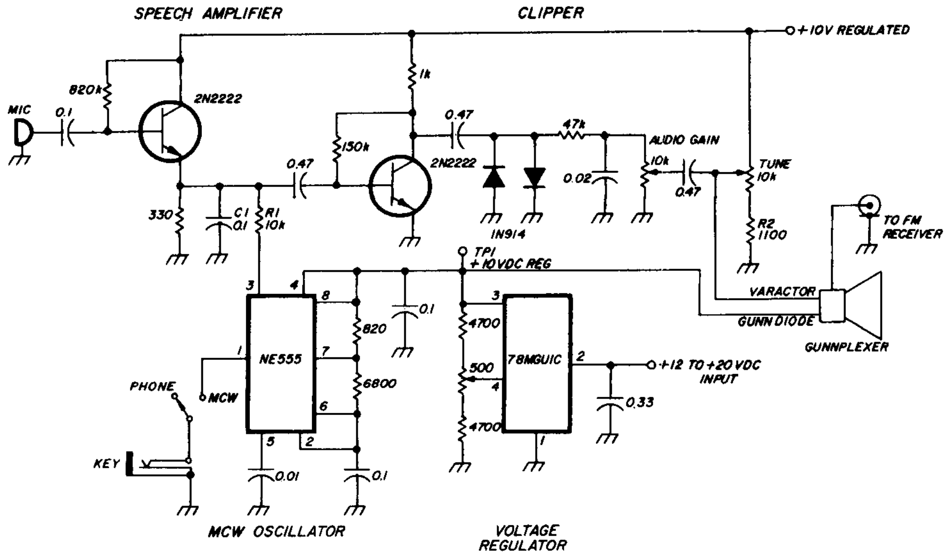


fig. 20. Circuit for a Gunnplexer transceiver without a built-in i-f receiver. In the original model, this circuit was built on perf board. Resistor R1 is adjusted for the desired tone level; R2 is set for a 1-volt drop.

(After an initial warmup of 30 minutes, two enclosed Gunnplexers in my shop remained on channel for more than a day.)

For closer frequency control you can either preheat the Gunnplexer (or use a proportional temperature control system as I suggested in an earlier article[1]) or use automatic frequency control (AFC). Gunnplexer temperature control would probably be a good choice for use at a base station, but because of the huge current drain of any heating system, AFC is better for portable use. In an AFC system any deviation in the average value of the i-f from the center frequency of the discriminator in the receiver will produce a dc voltage determined by the direction of the frequency deviation. This dc voltage is applied to the varactor in the Gunnplexer to bring it back on frequency. Note that the use of AFC must be limited to one end of a Gunnplexer link; the other end is allowed to run free.

In many cases, the AFC voltages for the Gunnplexer can be obtained from the i-f receiver. The AFC system shown in **fig. 18** was designed by DJ7OO for use with his 30-MHz receiver.[5] This same basic circuit can be used with other fm receivers by simply changing the values of resistors R1 and R2. In some cases the circuit will work as shown, but others will require more (or less) gain — which is set by the ratio of R1 to R2. The only other adjustment is R3, which should be set for a voltage drop of 1 volt.

In the center position of switch S1 the AFC is turned off; the two outer positions provide positive- and negative-going AFC voltage with increasing frequency.

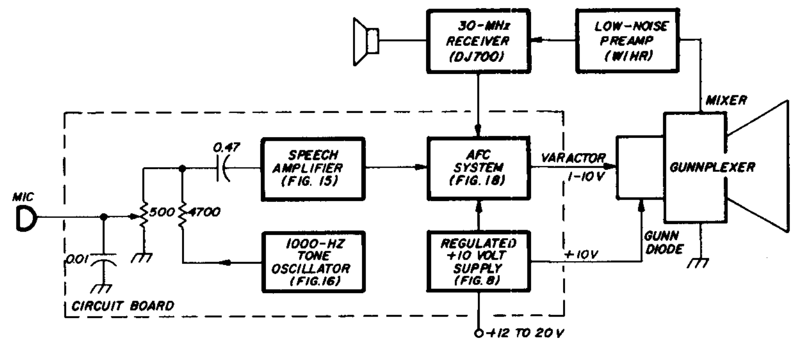
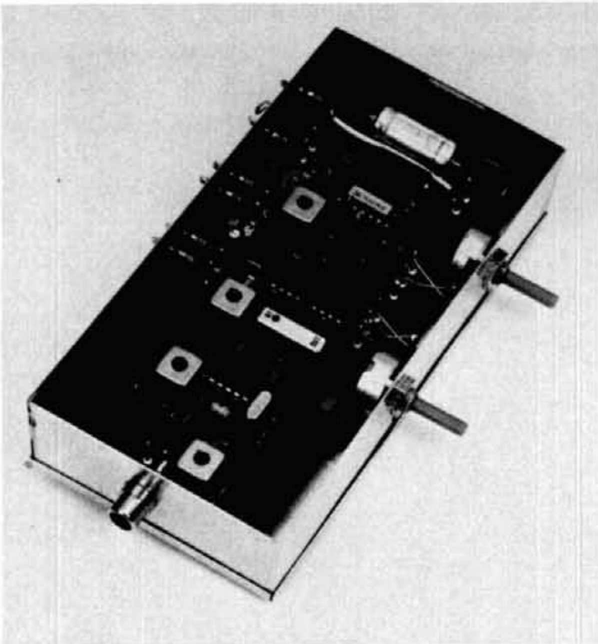


fig. 21. Complete Gunnplexer transceiver featuring high-performance speech amplifier with clipping and de-emphasis, crystal-controlled 30-MHz receiver, and low-noise preamplifier. A circuit board for the speech amplifier, tone oscillator, AFC system, and regulated power supply is shown in fig. 22.

Which is chosen depends upon whether the frequency of the Gunnplexer with AFC is above or below the free-running Gunnplexer without AFC. Assume the Gunnplexer with AFC is set to 10250 MHz (see **fig. 19**). If the free-running Gunnplexer is at 10280 MHz and drifting higher, the incoming signal is moving *upward* through the receiver passband. Therefore, a positive AFC voltage is required to shift the 10250-MHz LO up to recenter the 10280-MHz signal on the middle of the passband. If the free-running Gunnplexer drifts downward, the opposite occurs. In either case, however, the sense of the AFC voltage is the same (positive) as the necessary frequency shift.

Now consider what happens if the free-running



Wideband 30-MHz fm receiver designed by DJ7OO for use with Gunnplexer systems (described in the August, 1978, issue of *ham radio*). At the left is the mosfet input stage, followed by the SO42P crystal-controlled local oscillator and mixer, TDA1047 i-f strip, and TAA611 audio power amplifier. The two controls are for squelch and audio gain.

Gunnplexer is *below* the one with AFC at 10220 MHz. If it is drifting higher, the incoming signal is moving *down* through the receiver passband, and a *negative* AFC voltage is required to move the 10250-MHz LO down to shift the 10220-MHz signal to the center of the passband. Therefore, if the frequency of the Gunnplexer with AFC is above that of the free-running Gunnplexer, the sense of the AFC voltage is opposite (negative) to the necessary frequency shift.

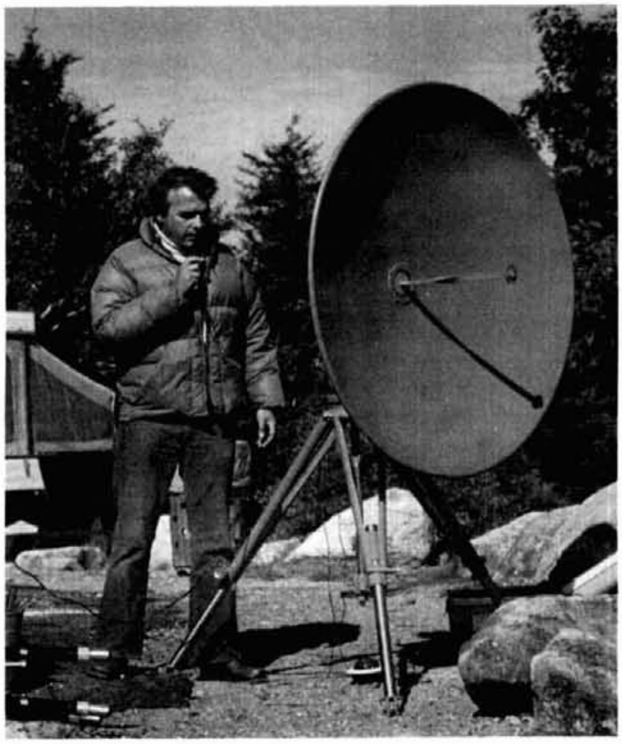
Obviously, the *sense* of the AFC voltage is extremely important. If the AFC sense is incorrect, it tends to chase the received signal out of the passband. In **fig. 19B**, for example, if positive AFC is used, upward drift toward 10221 MHz will reduce the AFC voltage, moving the LO toward 10249 MHz — the wrong direction! If the AFC has the wrong sense, you'll find it almost impossible to tune in the signal; in many cases the LO will actually oscillate back and forth across the receiver passband several times per second. If you've built a Gunnplexer system with AFC and have experienced this problem, now you know what caused it.

gunnplexer transceivers

To build a complete Gunnplexer transceiver, all you have to do is combine some of the previous circuits and build them into a single enclosure. Two examples are shown in the accompanying photographs. The first, which I call the "minimal" Gunnplexer system, is built into a 125 × 100 × 75 mm (5 × 4 × 3 inch) Minibox and doesn't include the receiver (a phono jack is provided so it can be used with a variety of external receivers). The other transceiver, which is built into a 225 × 150 × 125 mm (9 × 6 × 5 inch) aluminum utility box, includes a built-in 30-MHz receiver with a low-noise preamp and speaker.

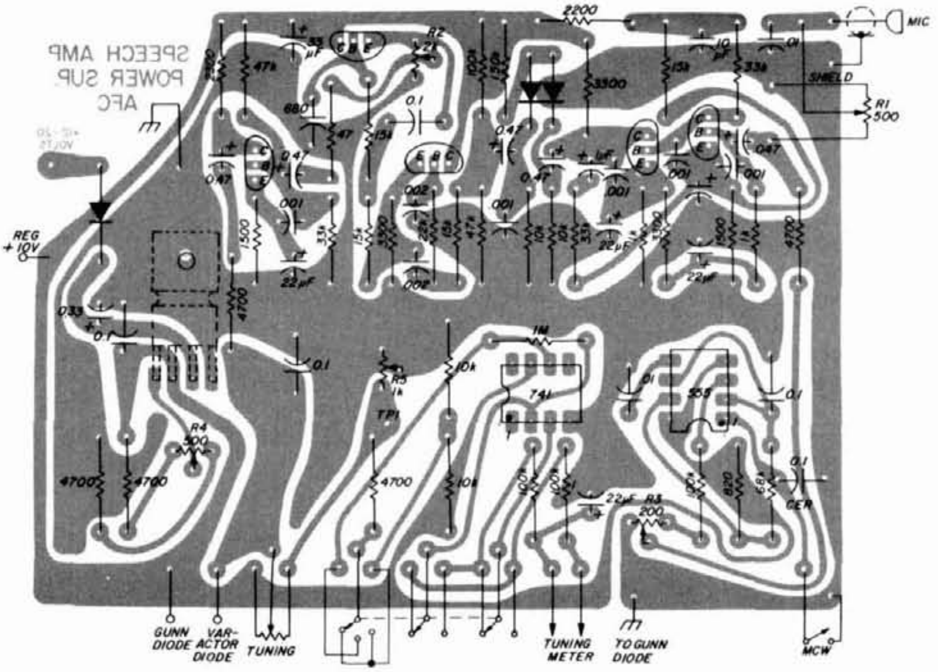
The circuit of the minimal Gunnplexer transceiver is shown in **fig. 20**. Basically, it consists of the two-transistor speech amplifier (**fig. 14**), 1000-Hz tone oscillator (**fig. 16**), and regulated dc power supply. Note that the lowpass filter at the output of the tone oscillator is combined into the speech amplifier. No receiver was included because at the time I built this transceiver I was still undecided about a receiver and wanted to try several options. Since it was built it has been used successfully with a variety of i-f receivers at 30 MHz, 100 MHz, and, more recently, 111 MHz (the New England spot for retuned fm broadcast receivers).

The Gunnplexer transceiver shown in **fig. 21** might be called the "deluxe" model. In addition to the built-in 30-MHz receiver and low-noise preamp[6], it features the high-performance speech amplifier with clipping, audio shaping, and de-emphasis (**fig. 15**),



10-GHz Gunnplexer system setup by the W1FC group on Pack Monadnock in New Hampshire during the September vhf/uhf contest. Two-way communications were established with Gunnplexer-equipped stations in Maine, New Hampshire, and Vermont.

fig. 22. Component layout for the printed-circuit board for the Gunnplexer transceiver. At the top of the board is the speech amplifier with clipping and de-emphasis. Below, right to left, are the 555 tone oscillator, 741 AFC amplifier, and 78GU1 voltage regulator. (Note that the 78GU1 is mounted on the foil side of the board.) In the speech amplifier, pot R1 sets the microphone gain; pot R2 is used to set maximum deviation. Pot R3 sets the tone voltage level into the speech amplifier; R4 is the +10 volt adjust, and R5 is set for +1 volt at TP1. The capacitors in the audio amplifier are tantalum types.*

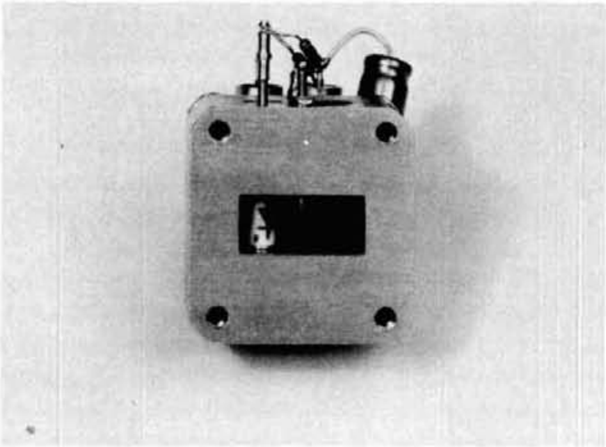


an AFC system, tone oscillator, and regulated power supply. To save space and improve reliability, these circuits are built on a printed-circuit board (**fig. 22**). For improved heatsinking of the 78GU1 voltage regulator, this IC is mounted on the foil side of the circuit board. In addition, an aluminum mounting spacer is used to conduct heat to the chassis. The result is a very cool-running voltage regulator, even with 500 mA of output current. In the transceiver this circuit board is mounted on the rear wall of the utility box. A 100 × 100 mm (4 × 4 inch) aluminum plate, 6 mm (1/4 inch) thick, is mounted in the bottom of the enclosure and tapped for a 1/4-20 screw. This is the standard thread for camera tripods sold in the United States.

When setting up this transceiver, first set the 500-ohm voltage adjust potentiometer, R4, for +10.0 volts at the Gunn diode, then adjust R5 for 1.0 volt at test point 1 (TP1). The tone output level adjustment, R3, is set for the same deviation as the microphone; this and the other audio adjustments are discussed later.

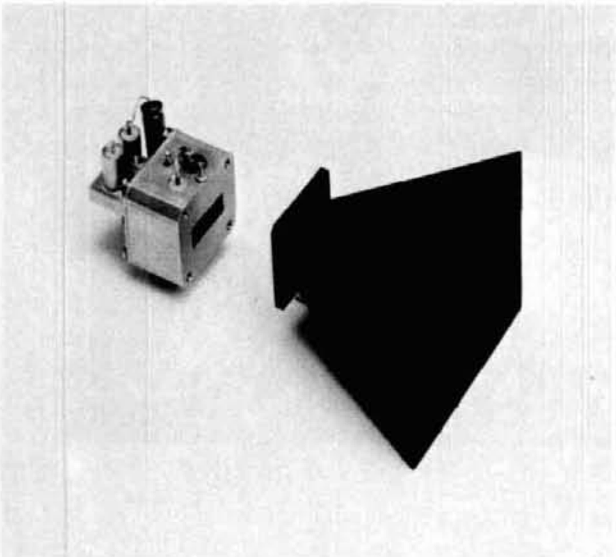
fig. 23. Full-size printed-circuit layout for the Gunnplexer speech amplifier, tone oscillator, AFC amplifier, and voltage regulator. Component layout is shown in fig. 22.

*Complete parts kits, including PC board, are available from G. R. Whitehouse, 10 Newbury Drive, Amherst, New Hampshire 03031.



Head-on view of the Gunnplexer showing the mixer diode, left, and ferrite circulator (black cylinder to right). The small screw which protrudes through the top of the waveguide is used to adjust mixer injection.

One feature of the transceiver which is not shown on the schematic should be mentioned: a small relay to turn off the speaker during voice transmissions. When communicating with a Gunnplexer system, the receiver detects both the signal from the distant station and the local transmitted signal. In addition to being annoying, this is sometimes the cause of unwanted howls and squeals because of audio feedback. To solve this problem, some builders have installed a spdt switch to transfer the audio output to a 4.7-ohm resistor. In my transceiver I installed a miniature spdt relay which is operated by the PTT switch on the microphone (most 12-volt relays work quite well on +10 volts). The speaker circuit isn't affected when the tone oscillator is used for CW, so I have a built-in CW sidetone system.



Microwave Associates 10-GHz Gunnplexer and 17-dB horn antenna. Receiver section is housed in waveguide section machined from large block of metal. This improves thermal stability of the unit.

waveguide flange layout

If you wish to mount your Gunnplexer inside an aluminum Minibox, you must match the waveguide and mounting screws to a cutout in the enclosure. There are feedthrough waveguide flanges on the market, but they're expensive and seldom make their way into the surplus market. The only alternative is to carefully lay out the mounting holes for the UG-39/U waveguide flange and then hand file a cutout to match the interior dimensions of the waveguide. This is difficult if you don't have access to a waveguide handbook because the screw holes are not at the corners of a square, as you might suppose, but are slightly offset as shown in **fig. 24**. This is done intentionally so it is impossible for a technician to cross polarize sections of waveguide.

To locate the mounting holes for the UG-39/U flange, prick punch the center and use a compass to swing an arc with a radius of 15.5 mm (0.61 inch) as shown in **fig. 24B**. Now use a carpenter's or machinist's square to draw two vertical lines which are tangent to the arc (**fig. 24C**). Using the same center point, swing another arc with a radius of 16.3 mm (0.64 inch) and use the square to draw two horizontal lines (**fig. 24D**). The screw mounting holes are located at the intersections of the straight lines. To check their location, swing an arc with a radius of 22.5 mm (0.884 inch); it should cross the center point of each of the hole locations (**fig. 24E**). When you are satisfied that the mounting holes are correctly located, drill the holes with a number 18 (4.3 mm) drill for the 8-32 mounting screws. Temporarily mount the Gunnplexer to make sure the holes mate with the tapped holes in the Gunnplexer flange.

After the screw holes have been located you can make the rectangular cutout for the waveguide. This cutout measures exactly 0.4 to 0.9 inch and is centered on the same point as the mounting holes. After scribing the outline with a square, I found the best approach was to drill out the center point with an 8 mm (5/16 inch) drill. This provides clearance for an Adel nibbling tool.

A word of warning: don't try to make the *finished* cutout with the nibbler; you're sure to botch the job. Use the nibbler only to make the rough cutout — within about 1 mm (1/32 inch) of the finished edge. Then carefully hand file the edges of the opening so they match the waveguide.

Temporarily install the Gunnplexer to check progress, but carefully wipe off the metal filings first so they don't get into the Gunnplexer. And don't leave the Gunnplexer in place while you're filing the opening — that's an open invitation to disaster!

setup and test

The easiest way to set up a Gunnplexer system is to get together with a friend and set up your 10-GHz stations at the same time. With two Gunnplexers running on the bench, it takes only a few minutes to adjust the speech amplifier and tone oscillator for best performance. Tests and adjustment of an AFC system take longer, but most work can be done in one evening.

The only problem you're apt to encounter with two Gunnplexers in the same workshop is high signal strength — if you have an S-meter, you can be sure it will be against the pin, regardless of the direction you point your Gunnplexers. However, wood makes an excellent microwave absorber, as does the conductive black plastic foam which is often used to protect CMOS integrated circuits. A small section of black foam placed across the waveguide will reduce the radiated signal by 30 dB or more; a section of 2 × 4 pine lumber in front of the Gunnplexer reduces signal strength by 10 or 12 dB. Once you have reduced signal strength to manageable levels, you can make the necessary adjustments. First set one Gunnplexer up with +10 volts on the Gunn diode and +4 volts on the varactor; unless tuned specially by the manufacturer, the operating frequency will be close to 10250 MHz. Now tune the other Gunnplexer to a frequency below the first where you hear the carrier, and carefully adjust the varactor bias for a zero reading on the carrier meter (if your receiver doesn't have a zeroing meter, adjust for maximum signal strength). Make a note of the varactor voltage; this Gunnplexer will now be tuned to 10220 MHz if a 30-MHz i-f is being used.

Now tune the second Gunnplexer above the first until you hear the carrier and carefully center the carrier in the passband of the receiver. Make a note of the varactor voltage (Gunnplexer tuned to 10280 MHz with a 30-MHz i-f). If you wish, you can now set the varactor voltage on this Gunnplexer to +4 volts and make similar measurements on the other unit. If you use a turns-counting dial on the varactor bias

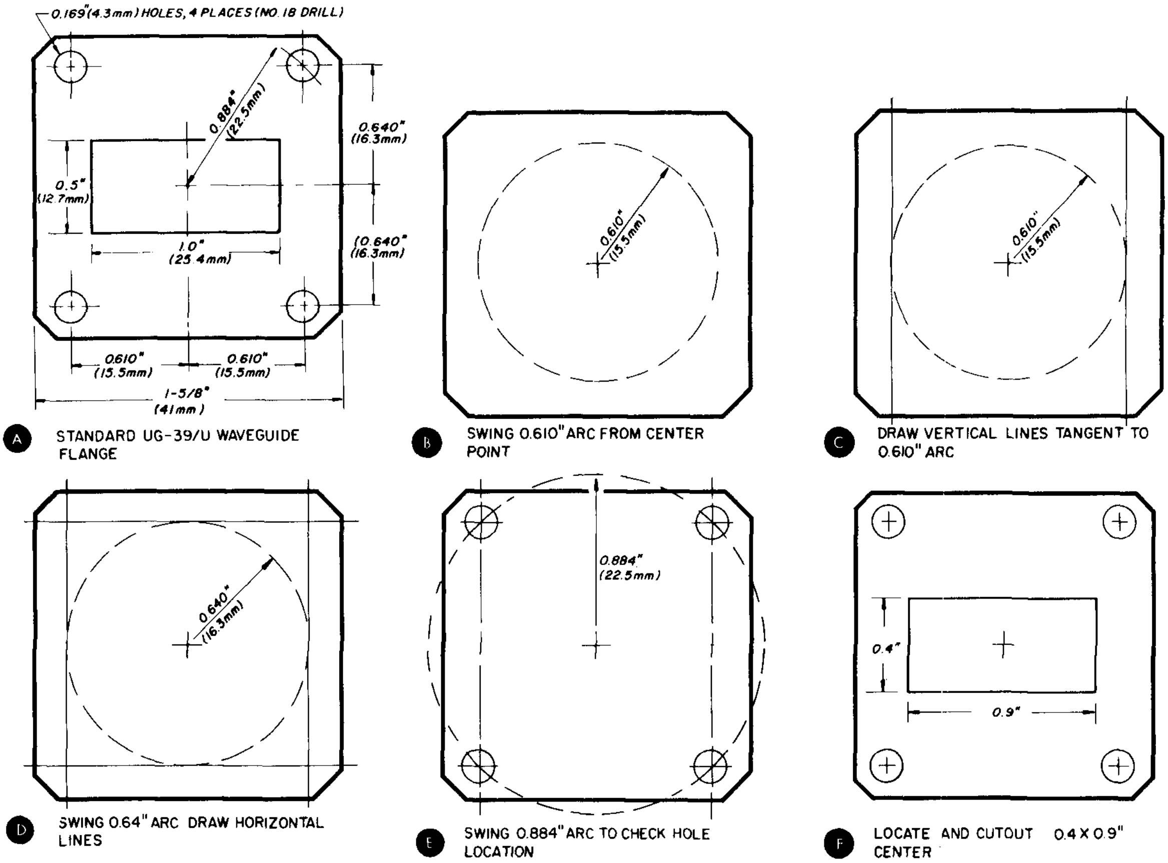


fig. 24. How to lay out the chassis to match a UG-39/U waveguide flange (used on all Microwave Associates Gunnplexers). Note that the flange holes are not symmetrical. Step-by-step instructions are given in the text.

potentiometer, it's helpful when mountain-topping to know which dial settings correspond to the operating frequencies of 10220, 10250, and 10280 MHz.

Now tune the Gunnplexers to one another and carefully center the carriers. Plug in your microphone and increase the speech gain control. You will note that the received audio signal will have excellent fidelity at a certain setting of the gain control, but, as gain is increased beyond that point, the signal becomes distorted. Back down the gain control to a setting slightly below that which causes audible distortion.

If you wish to measure the actual deviation of your signal, you can use the Bessel function relationship to determine the audio input frequencies at which the fm carrier will completely disappear; this technique is discussed in most of the popular vhf-fm books. **Table 1** lists the audio frequencies for carrier nulls at several popular deviations (use 75-kHz deviation for wideband fm receivers); it is not practical to use carrier nulls beyond the third.

In most cases it's not necessary to make an actual deviation measurement; reliable fm microwave communications can be obtained by a simple adjustment of the speech gain control for no audible distortion. Once the speech gain had been adjusted, turn on the tone oscillator and adjust the tone signal level for a signal strength approximately the same as for voice. If you have both input and output controls in your speech amplifier, set the output control for full deviation or minimum audio distortion with the microphone gain control set at about one-half full gain — this will leave plenty of leeway for microphones with higher or lower output. Set the tone oscillator level as before.

If you don't have a friend with a Gunnplexer, you can use the Boomerang system shown in **fig. 25**, which was originated by the San Bernadino Microwave Society. All you need is an X-band crystal mixer and a 1 to 2 mW local-oscillator source at 30 MHz (if you're using a 30-MHz i-f receiver). When setting up the mixer, be sure to provide a dc return (rf choke) for the mixer diode. Place the mixer 100 meters (300 feet) or so from the Gunnplexer. The transmitted signal from the Gunnplexer will mix with the 30-MHz

table 1. Audio frequencies which will produce a carrier null for various amounts of frequency deviation (use 75 kHz deviation for wideband fm receivers).

modulation frequency	deviation produced 1st null	2nd null	3rd null
2717.3 Hz	± 6.53 kHz	± 15.00 kHz	± 23.52 kHz
4528.9 Hz	± 10.89 kHz	± 25.00 kHz	± 39.19 kHz
5000.0 Hz	± 12.02 kHz	± 27.60 kHz	± 43.27 kHz
8666.8 Hz	± 20.84 kHz	± 47.84 kHz	± 75.00 kHz
10000.0 Hz	± 24.05 kHz	± 55.20 kHz	± 86.54 kHz
13586.7 Hz	± 32.67 kHz	± 75.00 kHz	± 117.58 kHz

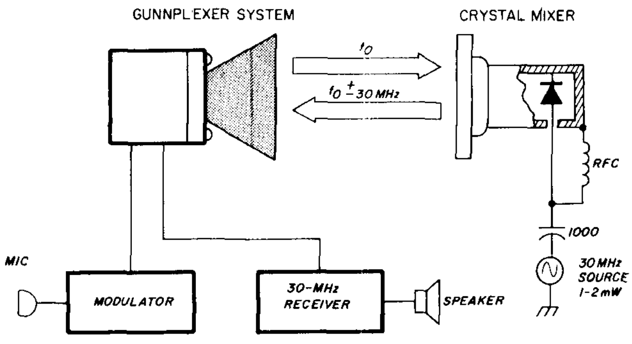


fig. 25. Boomerang system devised by the San Bernadino Microwave Society for testing microwave systems. It requires only an X-band diode mixer and 1 to 2 mW at 30 MHz. The mixer should be placed 100 meters or so from the Gunnplexer to eliminate i-f feedthrough; if the X-band mixer is too close to the Gunnplexer, radiation from the 30-MHz signal source will completely block the i-f receiver.

LO, be re-radiated, and picked up by the Gunnplexer receiver. With this system you can make all the adjustments discussed previously.

When using the Boomerang system don't place the X-band mixer too close to the Gunnplexer. If it is too close, primary 30-MHz radiation from the LO will feed directly through to the i-f receiver. You can tell very quickly if this is happening because the receiver will be completely blocked.

radiation hazard

Although 20 mW isn't usually considered to be very much rf power, in the Gunnplexer it's concentrated at the small, open end of the waveguide, so power density is about 6.2 mW per square cm (up to 19 mW/cm^2 for higher-powered Gunnplexers). This is considerably above OSHA's 10 mW/cm^2 safety limit. Fortunately, rf power density falls off to safe levels with a few feet (2 meters), but remember that your eyes are especially susceptible to damage from rf radiation — never look into the open end of a Gunnplexer while it's operating.

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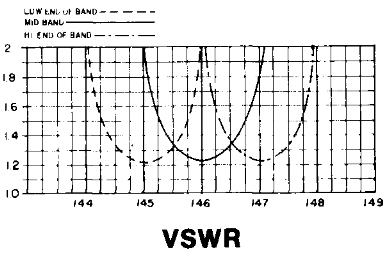

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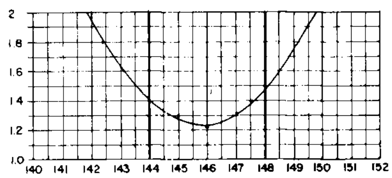

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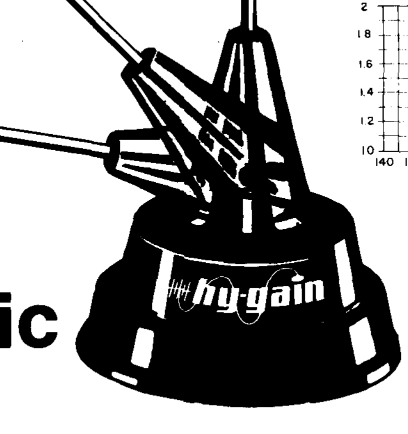

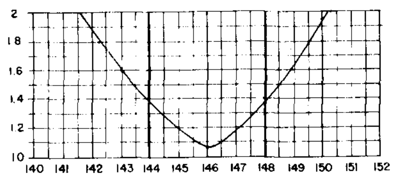

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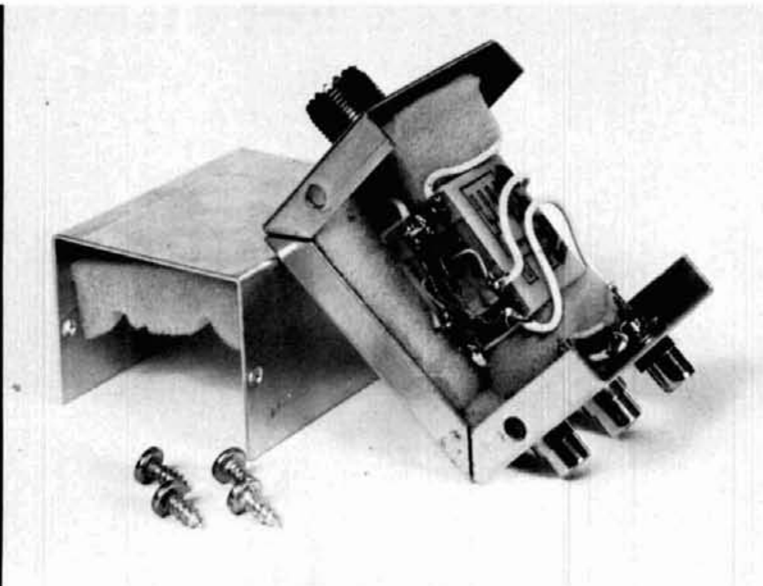

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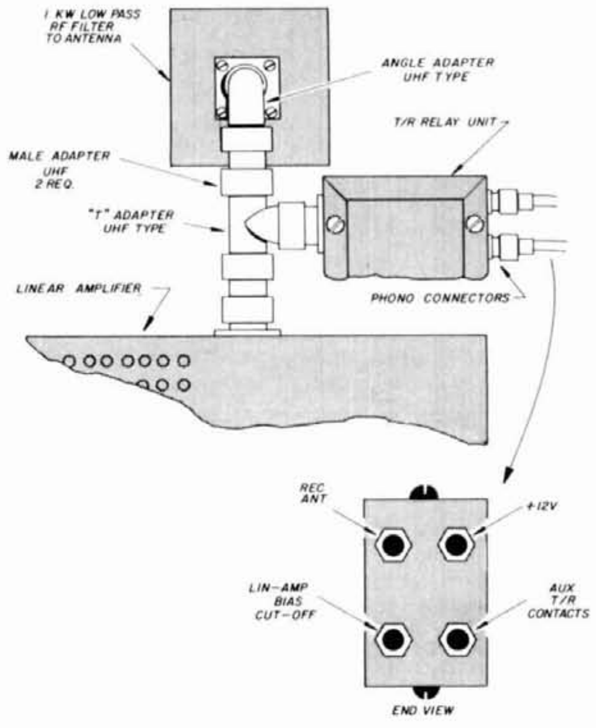

fig. 1. Full-scale drawing of the interconnections between the T/R relay unit, amplifier, and antennas. The four phono connectors, mounted on the small Minibox, are used for the connections to the receiver and control circuits.

By Nick Lefor, W1DB, 2A Knollwood Acres, Storrs, Connecticut 06268

Observations made over a period of years indicate the majority of amateurs still cling to the push-to-talk method of operating their linear amplifiers during CW and voice operation. Continued use (or abuse) of push-to-talk operation can be blamed, in a large part, for the loud clacking noise generated by transfer (exciter/final) relays installed in most linear amplifiers. In an otherwise quiet ham shack, this loud and rapid clacking can become very annoying during both CW and phone operation.

The T/R relay unit described in this article, and linear amplifier modification, will go a long way in reducing the noise generated by the linear amplifier transfer relay; it will also provide fast CW break-in and VOX operation.

Basically, the T/R relay unit and system is a free adaptation of the ideas suggested by Dick Frey, K4XU.[1] The T/R relay unit consists of permanently connecting the operating antenna to the linear amplifier rf output connector through a UHF T connector. As seen in **fig. 1**, the T/R relay unit acts as the interconnection between the exciter/amplifier, receiver, and antenna. When the amplifier is being used, the STANDBY/OPERATE switch, having been rewired, holds in the amplifier's internal transfer relay, with the T/R unit controlling the operating bias. During exciter-only operation, placing the switch in STANDBY will bypass the rf around the amplifier.

construction

The T/R relay unit consists of a small, aluminum utility box, approximately 7.6 × 7.6 × 5.1 cm (3 × 3 × 2 inches [Radio Shack 270-235]), UHF and phono connectors, and a miniature dpdt 12 Vdc relay [Radio Shack 275-206]. The miniature relay is wired between the connectors using no. 22 (0.6mm) AWG wire. In addition, it's supported by small urethane pads which also serve as sound absorbers.

operation

When K2 (see **fig. 2A**) is operated by the exciter/transceiver auxiliary T/R contacts, K2A transfers the receiver's antenna input from the antenna to ground. K2B shorts the amplifier cutoff bias resistor (R2, **fig. 2B**) to ground, thereby placing the proper operating bias on the amplifier tube. The 1N914 diodes are installed for receiver input protection. The 1N4006 diode, installed across relay coil K2, is used for transient switching protection. This diode has a tendency to delay the release time of K2, however this delay is not noticeable, even at high keying speeds. The modifications, as outlined, are for a TENTEC "Triton IV" transceiver and a DenTron "MLA-1200" linear amplifier. However the principles can be applied to other linear amplifier-receiver/transceiver combinations.

results

Although the response time (T/R switching) and quieting does not approach that outlined by Dick Frey's article, the results have been quite satisfactory — and less expensive. Fast CW break-in at the 1-kW input level has been retained, with no transients present on either transmitting or receiving. A gratifying improvement is the absence of the noise generated by the amplifier transfer relay. Note that this system of break-in can be applied only to receiver/exciter combinations and transceivers having a separate receiver antenna input.

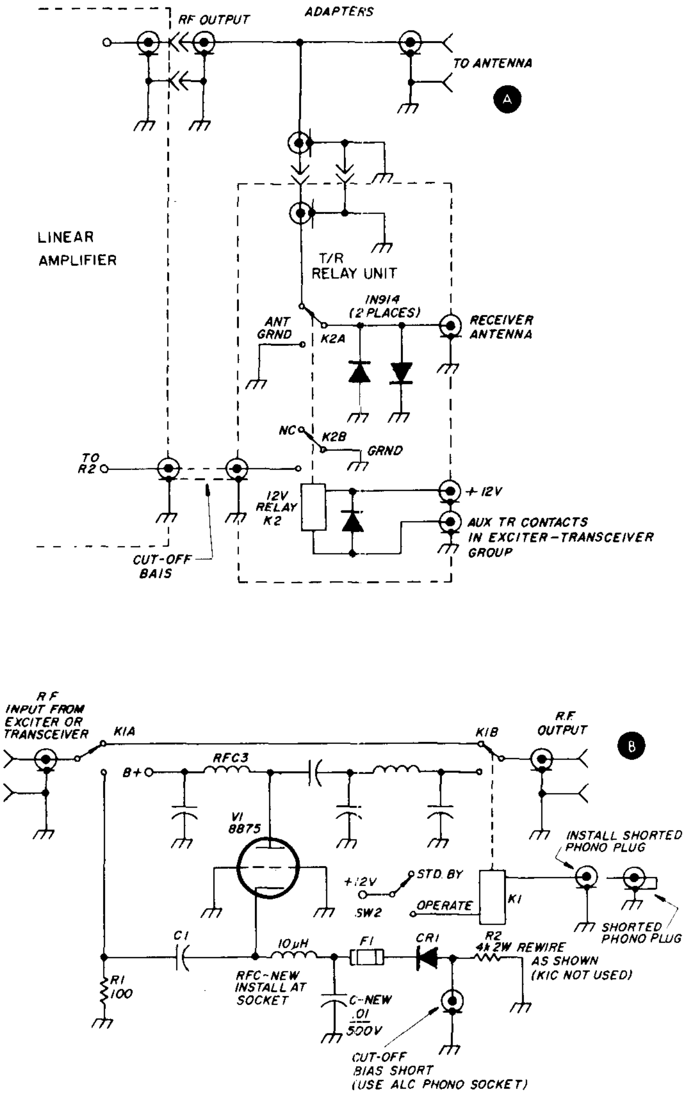

fig. 2. Schematic diagram of the T/R relay and modifications to the DenTron MLA-1200 amplifier. The wiring within the Minibox containing the double-pole, double-throw is at (A). In (B), the MLA-1200 has been modified to provide remote switching of the amplifier's bias. Additional components have been installed to prevent rf from getting into the bias line.

I wish to acknowledge the helpful suggestions of Milt Hirsch, W1AUB.

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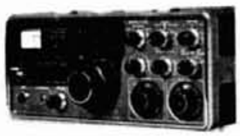
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adjustable-voltage 5-ampere power supply

High output current, adjustable voltage, and a low parts count highlight the benefits possible with the Fairchild μA78/79 hybrid voltage regulators

Fairchild has recently introduced its μA78HGC (positive) and μA79HGC (negative) "hybrid" voltage regulators, which should find wide application among amateurs. These regulators are capable of supplying current in excess of 5 amperes over a 5 to 24 volt output range (−24 to −2.2 volts for the negative regulator). Load and line regulation is better than 1 per cent. The hybrid nature of these regulators is the result of mating a low-current voltage regulator IC, a Darlington series pass transistor, and two short-circuit detection transistors in one 4-pin TO-3 package. A block diagram of the device is shown in **fig. 1**. The output voltage is set by two external resistors. This design greatly simplifies the construction of relatively high-current power supplies.

The cost of the device is competitive with that of the discrete components. The parts count is a mere eight, including power transformer, rectifier, and filter capacitor, and the numerous possible applications include solid-state power amplifiers, vhf rigs, large digital projects, repeater supplies, audio equipment, and variable bench supplies.

table 1. Characteristics of the Fairchild hybrid.

voltage regulators	
Input Voltage Maximum	40 volts
Output Current	5 amps
Minimum Input-Output Differential	3 volts
Maximum Input-Output Differential	25 volts
Line Regulation	1 per cent V_{out}
Load Regulation	1 per cent V_{out}
Control Pin Voltage	4.8-5.2 volts
Short Circuit Current Limit	7 amps

Table 1 summarizes the electrical characteristics of this device family, which also includes three fixed-output devices with otherwise identical specifications: μA78H05C (5 volts), μA78H12C (12 volts), and μA78H15C (15 volts). The fixed-output regulators come in a standard 2-pin TO-3 case and include internal voltage-set resistors.

All of these regulators have thermal overload protection against excessive dissipation or current drain, along with internal short-circuit protection to limit current output. Safe area protection is provided for

By James S. Robbins, Esq., N1JR, c/o Horovitz, Gordon, and Robbins, 6 Beacon Street, Boston, Massachusetts 02108

the output transistors. When a short circuit is seen by the regulator, the rise in internal temperature puts it into thermal overload, shutting down the device for as long as the current demand generates excessive heat. The short circuit current limit is 7 amperes.

The basic positive regulator circuit (78HGC) is shown in **fig. 2**. R1 and R2 may be determined by the simple equations shown with the circuit. The nominal reference voltage on the control terminal is 5.0 volts (4.8 to 5.2 volts). To produce the recommended 1.0 mA current flow in the control string would require making $R2 = 5k$ *ohms*. With $R2 = 5k$ *ohms*, the output voltage becomes $V_{out} = [(R1 + R2)/R2] \bullet$ *control voltage* (where R1 and R2 are in k-ohms). For example, if the supply is to provide 13.8 volts and R2 = 5k ohms, then R1 must equal 8.8k ohms. Precise setting would require trim pots.

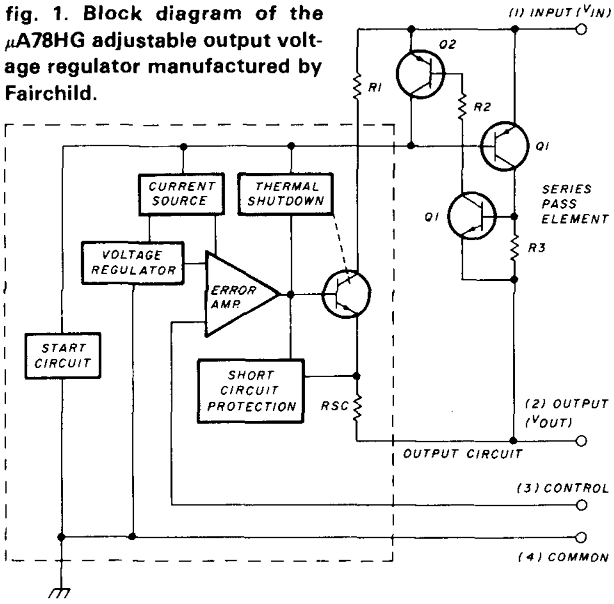

fig. 1. Block diagram of the μA78HG adjustable output voltage regulator manufactured by Fairchild.

As with virtually all such regulators, input and output capacitors should be used to improve transient response and to prevent oscillation of the regulator under certain feedback conditions. These capacitors also provide rf-field protection. Tantalum capacitors are preferred, but good quality ceramic discs may be used. Mounting should be as close to the device as possible.

The four-pin base diagrams (top view) for the regulators are shown in **fig. 3**. Note that the pin-outs for the two devices are different. The case is electrically isolated from the internal circuitry in the four-pin adjustable devices, but is the common in the fixed-output regulators.

Mounting may be accomplished with or without a socket. I have used a modified TO-3 socket by removing the center (collector) pin and drilling two additional holes for pins 2 and 3. Mounting R1 and R2 directly at the regulator will significantly improve the load regulation of the device.

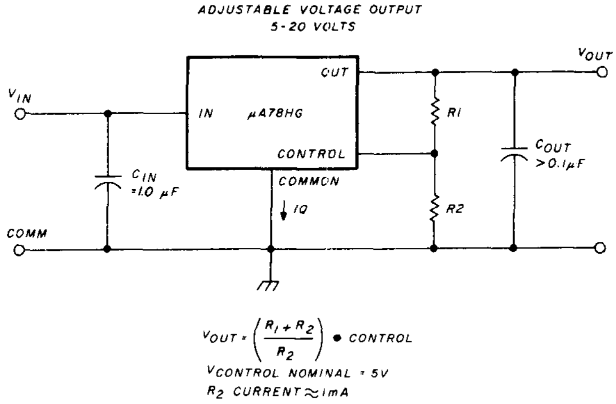

fig. 2. Typical circuit configuration to provide an adjustable output voltage. As discussed in the text, the resistor values are selected for approximately 1 mA of current flow in the divider and also to provide a control voltage input of 5 volts.

This series of regulators is rated for 50 watts of internal power dissipation at a case temperature of 25°C. Increased case temperature, of course, reduces this rating. A graph of maximum power dissipation versus case temperature is shown in **fig. 4**.

To achieve rated performance, attention must be paid to both heatsinking and input voltage, which are interrelated. Under normal operation the regulator will see some input voltages greater than that demanded as its output. The minimum input-output differential should be approximately 3 volts for proper regulation. The greater the difference between the input to the regulator and its output, the greater the dissipation required by the device (actually, by its internal pass transistors). By tailoring the input voltage to the output voltage, heatsinking requirements are reduced, *i.e.*, less heat must be dissipated in normal operation. To draw 5 amps from the regulator would set a maximum limit on the input-output differential of 10 volts. A lower differential reduces the heat to

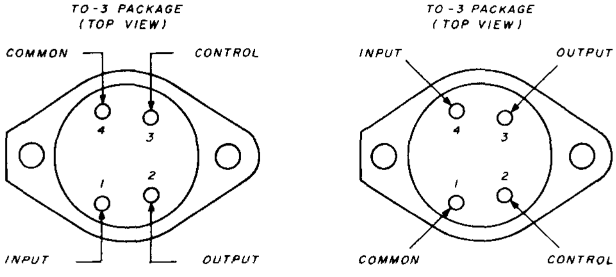

fig. 3. Pinout diagrams for the positive and negative voltage regulators (78HGC and 79HGC, respectively).

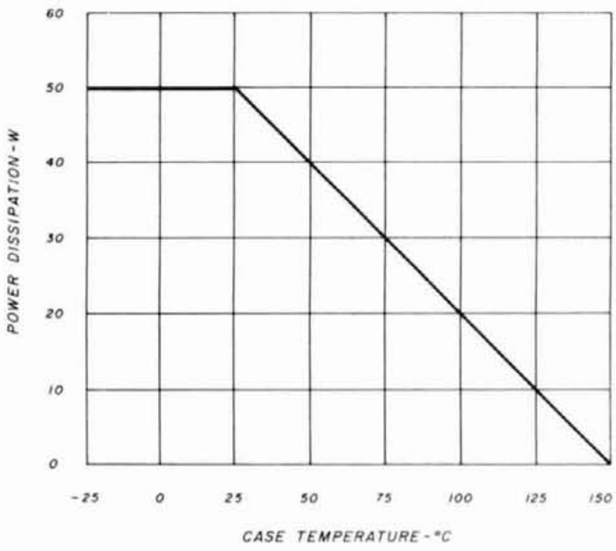

fig. 4. Graph of the maximum power dissipation for different case temperatures.

be dissipated. For example, a 13.8-volt supply drawing 5 amps and fed by a 24-volt input would require heatsinking sufficient to dissipate approximately 50 watts in normal use. This same supply fed by an 18-volt input must accommodate only slightly over 20 watts.

Many transformers may be easily modified to adjust their output voltage. Generally, the secondaries of these low-voltage transformers are on the outside and are readily reached after the laminations are removed. A count of the secondary turns will yield the voltage-turn ratio, making it a simple matter to remove (or, for that matter, add) the necessary turns. What you are looking for finally is an output voltage (after rectification and filtering) that, with full load, is only slightly above the 3-volt minimum input-output differential.

Heatsinking must keep the junction temperature below 125°C to meet specifications. Typically, a sink with a thermal resistance of approximately 1.5°C/watt would be adequate. Proper mounting, along with the use of a good thermal compound, is required.

This series of hybrid regulators from Fairchild offers a significant reduction in the parts count and complexity of power supplies. Its substantial curent capacity, along with regulation quality and device protection, make it an economical solution to a wide variety of amateur power-supply applications. The zener diode is increasingly being moved out of the power supply business as integrated regulators become more diverse. These Fairchild regulators are one more step in that evolution.

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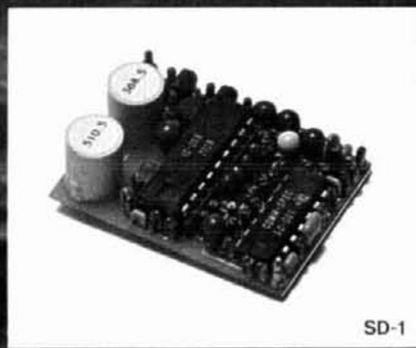

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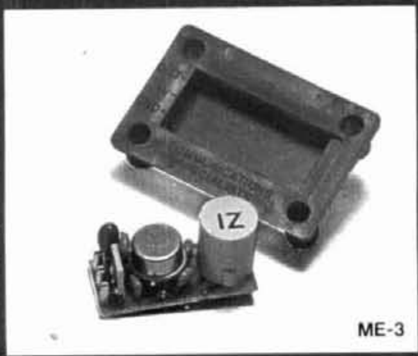
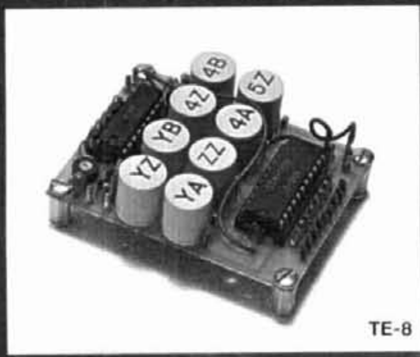


ME-3



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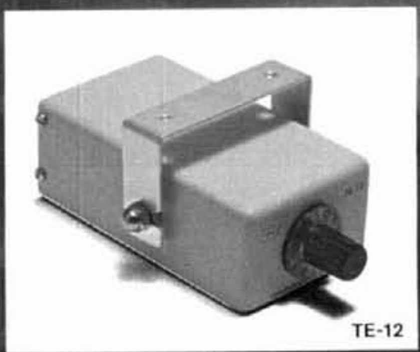

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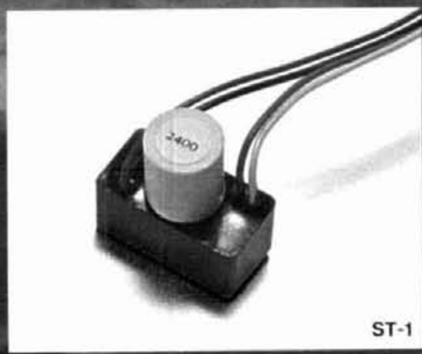

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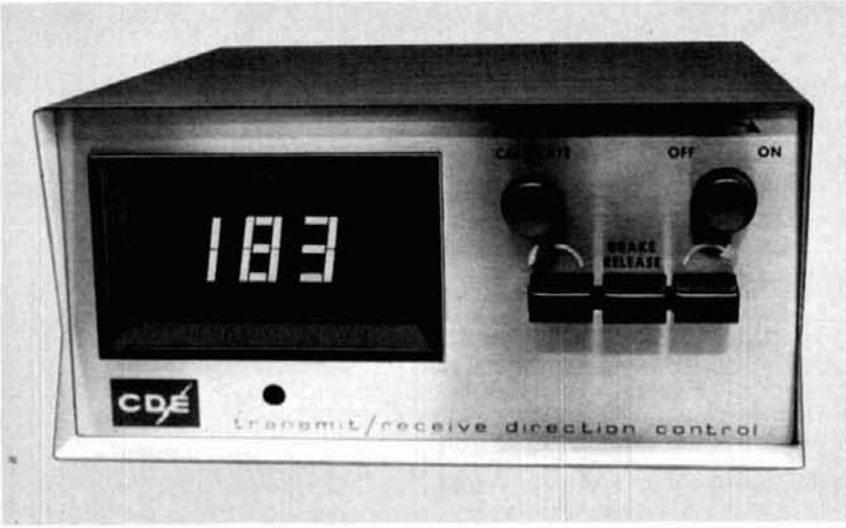


digital readout

for the Ham-3 rotator

Add a digital readout to the Ham-M rotator series by incorporating this simple but accurate analog-to-digital converter

It appears that Amateur Radio has gone digital. The signs of change are all around the shack. First came the digital IC keyer, which later had a digital memory added. Digital frequency readout was once a luxury; now, it's a standard feature of most new transceivers. Every shack, of course, now sports a digital clock built from a $3 clock IC. With the exception of the keyer, all the "digital" applications are merely conversions of analog data to digital *readout*. Since this trend is likely to continue, it's worth looking into.

Electronic analog-to-digital conversion can be accomplished using several different techniques.* These include parallel (or "flash") tracking, successive approximation, or single- and dual-ramp converters. The flash converter is often used in extremely high-speed applications. Successive approximation is a general-purpose, medium-speed approach, while the dual-ramp or dual-slope is suited to low-speed applications. Integrated circuits are now available at reasonable cost to perform each of these conversions. In choosing a converter, you must consider several aspects: speed, accuracy, resolution, and output format. The actual analog signal being converted must also be considered. Is it a voltage or a current? Perhaps the best way to illustrate the reasoning behind a data-conversion project is by example.

The largest analog indicator in my shack is the meter on my HAM-3 control box, an obvious choice for digital readout. First, consider the A-D converter. Speed is not essential. Conversion times of a few hundred milliseconds are acceptable, so a dual-slope converter is adequate. The accuracy of this system is likely to be limited by the linearity of the Ham-3 indicator system, since most converter products are within 0.1 per cent accuracy. The Ham-3 indicator has an accuracy of about 5 degrees.[1] Resolution is a term describing the number of discrete values that can be recognized, in the same way that digital frequency readouts have resolution limitations. It seems foolish to have rotator readouts to tenths of a degree. A resolution of 1 part in 360 is adequate.

Since converter manufacturers produce both binary- and BCD-output devices, output format must be chosen. In this application, since the readout is a seven-segment visual display, the BCD output is the

*For detailed discussions of conversion techniques an excellent text, *Analog-Digital Conversion Notes*, is available from Analog Devices Incorporated, Norwood, Massachusetts, for $5.95.

By Doug Grant, K1DG, 20 Oak Street, Winchester, Massachusetts 01890

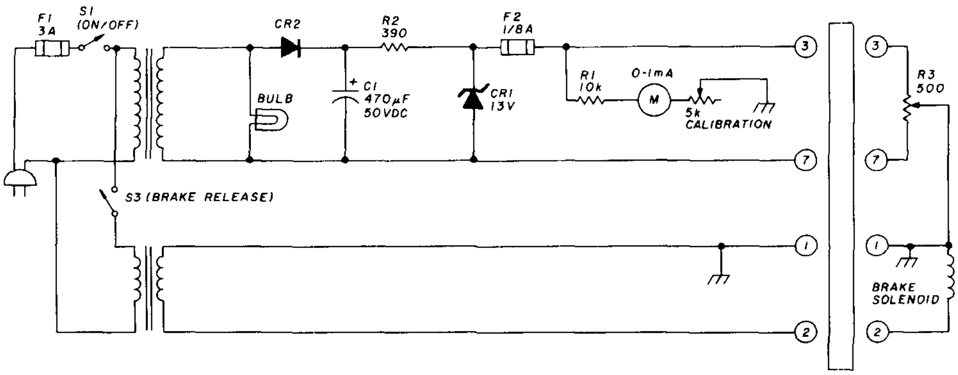
best choice. If you wanted to control the station from the shack computer (no doubt many hams are already considering this), a binary output would be better since computers tend to think in straight binary.

The Analog Devices AD2020, a 3-digit BCD output A-D converter, fits the requirements. It is a low-cost, low-speed, 3-digit BCD output converter widely used in digital panel-meter applications. It is an excellent choice for the HAM-3 digital display because it requires a minimum of external components; the readout is in millivolts. If a 0-359 millivolt signal representing the antenna heading is generated, the IC receives a convenient scale requiring no special conditioning.

signal conditioning

First, consider the original indicator circuit. Referring to **fig. 1**, the 13-volt zener reference is applied directly across the 500-ohm slide wire potentiometer inside the rotator. The wiper of the pot is connected through a 10k-ohm fixed resistor, the 5k-ohm calibration pot, and the meter to the plus side of the 13 volts. The current flowing through the meter is 1 mA at full scale, representing full clockwise rotation. When the rotator is moved to the full counterclockwise position, no current flows. Unfortunately, CDE chose to return the wiper of the indicator pot through the "ground" line, which also carries the ac for the brake and motor circuits. This causes problems with the digital display that aren't apparent when only the original analog meter is used. More on this later.

If you consider the voltage at the wiper of the pot with respect to the minus side of the regulated 13-volt supply, it varies linearly from 0 volts at full clockwise to 13 volts at full counterclockwise. A resistive voltage divider must be used to reduce this to a usable 0-360 millivolt range. In addition, this divider must have a high enough input impedance that it doesn't load down the pot. At mid scale, the pot represents a source impedance of 250 ohms, decreasing to zero at either extreme of its travel. The resistive divider shown in **fig. 2**, 100k-ohms and 2.49k-ohms, will not cause loading problems. In addition, the 100 meg-ohm input impedance of the AD2020 will not cause errors due to loading effects on the equivalent source impedance of the voltage divider.



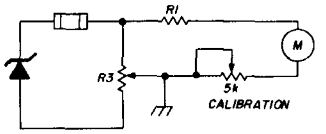


fig. 1. Schematic diagram of the original Ham-3 control circuit. The metering circuit has been redrawn for clarity. Note that the zener reference is floating; the bottom end is not grounded.

circuit description

Now that the required signal conditioning has been accomplished, support for the AD2020 chip must be examined. Very little additional circuitry is required. The displays can be any common-anode LEDs. Liquid crystals can be used, at the added expense of some additional circuitry. Personally, I like the LEDs, since they are more visible under the cowl of the control-box cover. Driver transistors for the LEDs can be any pnp transistor capable of delivering about 100 mA. The AD2020 is designed to mate with the Fairchild 9374 decoder/driver chip. This chip differs from the commonly used 7447 in that it has on-board current limiting and requires no resistors. Also, the displays for numbers greater than BCD 9 are different. When used as a pair, the decoding provides EEE for positive overload and --- for negative overload. If a 7447 is used, the − sign decodes as a C. The blanking inputs use different logic on each of these chips, so use caution is you substitute. Current-limiting resistors of 330 ohms should also be used with the 7447. The integrating capacitor is shown on the AD2020 data sheet at 0.27 μF. I used 0.1 μF with good success, so this value doesn't appear too critical.

Power for the readout circuit is derived from available voltages in the control box (see **fig. 3**). Since the services of the indicator lamp are no longer required, it can be removed. Once the lamp is removed, the instrument transformer in the control box is capable of furnishing the approximately 150 mA required by the digital readout circuit. A separate regulator, such as the LM309 or a 7805-type, is used.

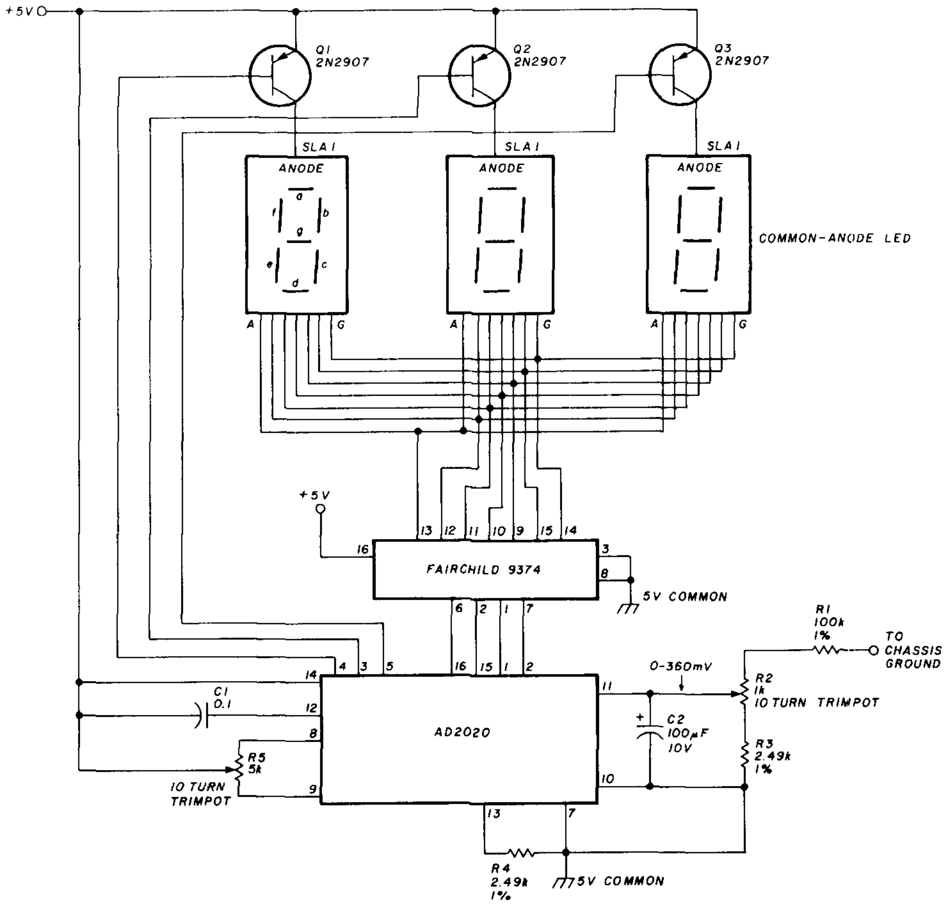


fig. 2. Diagram of the digital readout system. The 5-volt common line is not chassis grounded; it is tied to the bottom of the zener reference. *C2, across the input of the A-D converter, is used to prevent the ac voltage developed across the cable resistance from producing an erroneous readout.*

This regulator is supplied from the half-wave rectified and filtered dc from the transformer, tapped off points 11 and 13 on the power supply board of the Ham-3. Point 13 is treated as the "ground" for this supply. A heat sink *must* be used on the regulator, or separate regulators should be used for display power and for power to the AD2020 chip.

Consturction of the circuit is not terribly critical. I built the prototype on perforated board cut to fit behind the original meter bezel. A scrap of rubylith was used as a red filter to conceal the other components on the board and to yield a nice-looking front panel.

calibration and antenna positions

In order to keep the circuit simple, the readout is based on a south-centered scale. This way, one rotation extreme represents 0 degrees and the other represents 360 degrees. In a north-centered system, full clockwide represents 180 degrees, midscale is 360 degrees or 0 degrees, and full counterclockwise represents 180 degrees again. This presents a more complex problem. A 180-millivolt offset must now be switched in and out, requiring a comparator, relay, and reference supply. In my opinion, the headaches of trimming such a circuit outweigh the hassle of climbing the tower to turn the beam 180 degrees inside the rotator. In addition, changing the stop to north from south has another hidden advantage. In general, propagation follows a clockwise route. This means that conditions tend to favor Europe, then Africa, swinging south through the Americas, on into the Pacific, and finally to Japan. In the original configuration, having the stop at south made you swing your beam almost a complete revolution in order to follow the propagation as the peak passes due south.

When you change antenna position, first turn the rotator full counterclockwise. Then turn the antenna north with enough feedline slack to allow a full clock-wide rotation. Finally, reverse the connections to terminals 3 and 7 on the back of the control box. This is done to provide a full-scale voltage at full clockwise rotation. As originally configured by CDE, full clockwise provides full-scale *current* and zero voltage at the wiper of the pot relative to pin 7.

Calibration of the circuit is fairly simple. The original CALIBRATE button on the control box now serves no function. First apply power to the unit with the rotor in the full counterclockwise position. After a few minutes' warmup, adjust the zero pot, R5, for a reading of 000. Now rotate the antenna full clockwise. Then adjust the voltage divider trimpot, R2, for a reading of 360. The readout is now fully calibrated.

When I first installed the readout in my Ham-3, the display was rock stable until the brake release switch was pressed. As **fig. 4** shows, a large amount of brake and motor ac current flows through the common ground connection, causing the display to jump wildly. The problem was solved by placing C2, a 100-μF electrolytic capacitor, across the inputs to the AD2020. This capacitance represents a low impedance to 60 Hz ac and reduces the effects of the ground currents to less than 1 count. In some cases, rf bypassing might also be required. A .001-μF ceramic capacitor should provide adequate rf filtering.

summary

Before long, dozens of other analog functions around the ham shack will be converted to digital, either for readout or for computer control. The same considerations discussed in this article will arise in any situation requiring analog-to-digital conversion. As converter ICs become increasingly available to the amateur, an understanding of the underlying principles will become important.

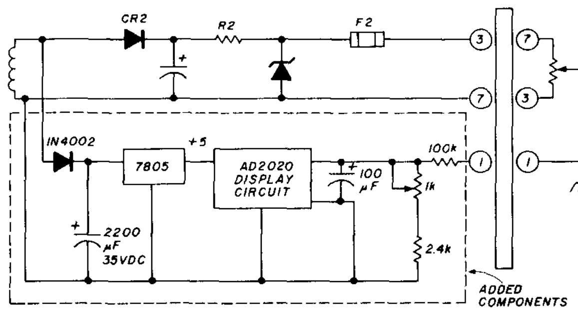


fig. 3. Wiring diagram of the modified indicator circuit. Wires on pins 3 and 7 of the terminal strip have been reversed, causing the readout to increase as the antenna is turned in a clockwise direction.

Consider the following scenario. The station digital clock indicates 0000 UTC, signaling the station computer that the contest has begun. The receiver

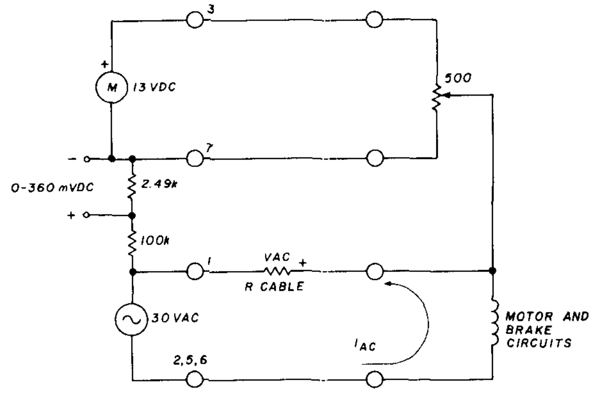


fig. 4. Equivalent circuit diagram of the control box used to illustrate the ac ground loop problem. The ac current flowing through the cable resistance causes a large ac voltage to be added to the direction indicating voltage at pin 1. Filtering across the 2.49k resistor is more effective, since a capacitor across terminals 1 and 7 is effectively shorted out when the pot reaches either extreme of its travel.

tuning algorithm is initiated, applying voltage through a digital-to-analog converter to a varactor in the receiver vfo. A signal is found, and the program jumps to the identification routine, including the Morse code translator. The station is identified and found to be calling CQ TEST. A quick check through memory shows that the station is not a duplicate. Elsewhere in memory, the correct beam heading is found. The rotator position is read in from its analog-to-digital converter, and the computer determines in which direction to begin turning the antenna. At the correct heading, signal strength is read from another A-to-D, and the RST for the exahcnge is computed. The keyer speed is adjusted and the computer now calls the other station. When the QSO is completed, the computer logs the contact and the sequence repeats. With an advanced system like this, a contest operator can relax and watch the football game on TV while his station operates itself and prepares a printed, duplicated log within minutes of the end of the contest.

references

1. Richard Klinman, W3RJ, "How to Update Your Ham-3 rotator," *CQ*, June, 1978, page 34.

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anodizing aluminum in the amateur workshop

Complex chemical processes for treating aluminum are translated into simple procedures for your home lab

Aluminum is used in many construction projects. But how do you decide on which type of aluminum to use? If you're interested in making panels, chassis, or boxes to house equipment, there's a right way to process the metal for durability and appearance. This article gives some pointers on how to process aluminum by anodizing, a chemical process that can be used in your workshop. Also included is information on how to apply colored dye to aluminum parts using simple procedures.

Aluminum is one of the most abundant elements on earth, forming about 8 per cent of the earth's crust. It's relatively inexpensive, easily machined and worked, lightweight yet strong, and an excellent electrical conductor. Its disadvantage, when uncontrolled, is its pronounced affinity for oxygen: a process called *corrosion*.

Aluminum oxidizes rapidly. Its natural surface breaks down, causing it to be unsuitable for applications where a long-term stable surface is needed. In ordinary atmospheric environments, even when few pollutants are present, alloyed aluminum surfaces oxidize within moments. The oxide is invisible to the naked eye; even the apparently bare surface of a recently machined aluminum part is immediately coated upon contact with atmospheric oxygen.

controlling oxidation

The formation of surface aluminum oxide can be controlled by anodizing. An electrochemical process is used to form the crystalline structure known as gamma aluminum oxide (γAl_2O_3) in an electrolytic cell, with the item to be anodized becoming the anode in the cell. The nature of the anodized metal has particularly significant physical characteristics:

1. Extreme hardness, approaching that of diamond
2. Electrical nonconductivity
3. Extreme porosity on a molecular scale

The gamma aluminum oxide film is closely related structurally to other oxides of aluminum, such as those used in manufacturing synthetic grinding wheels, and commonly substituted for natural corundum. Synthetic sapphires and rubies are, in fact, oxides of aluminum. Even though several different compounds are designated aluminum oxide (Al_2O_3), the crystal lattice structure takes on many quite

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peculiar variations, hence the designation of the anodic film as the *gamma* aluminum oxide.

Aluminum oxide coatings, or films, vary greatly from transparent to opaque, depending on film thickness and also on the alloying elements present in the aluminum alloy used. The film thickness is controllable, and can be from one to twenty microns.* The fact that the film thus generated is molecularly bonded to the aluminum and has a porosity that can be dyed makes an anodized film the most durable and useful of all possible finishes for this metal.

The porous surface of the gamma oxide film, whether dyed or left clear, is easily converted by immersion in boiling water to the closed, or sealed, crystalline state of the monohydrate of aluminum oxide, known as boehmite, designated $Al_2O_3.H_2O$ (or more correctly $AlOOH$). Boehmite has a large volume/area ratio of aluminum; therefore, the volume of anodized film is increased to close the pores, or *seal* the film. The conversion of the simpler gamma aluminum oxide to the boehmite structure makes the anodized surface unstainable, the dye unleachable, and the item so treated remains permanently dyed in the chosen color.

the anodizing process

Aluminum is anodized by immersing it in an aqueous electrolytic solution in which the aluminum item to be anodized becomes the anode (positive pole). A direct current is passed to it from the cathode (negative pole). Oxygen released from the water combines with surface aluminum molecules to form aluminum oxide; the crystalline lattice is of the gamma form. Although the acid electrolyte is not *used* in the *oxide-forming* reaction, it influences the characteristics of the formed film.

Two common methods of electrolytically producing an anodic film on aluminum offer different properties in the formed anodic film. The two methods use different acids in the electrolyte, chromic or sulphuric. These methods are discussed at length below.

alodizing

An alternative method of protecting aluminum is called alodizing. This method provides no color choice and results in only about a 3-micron (3×10^{-3} mm or 1.2×10^{-4} inch) film thickness. This process is a chemical-dip treatment, which produces an electrically conductive coating, usually of a smutty, mustard-like color. After buffing, alodizing does offer a degree of protection to the otherwise easily corrodible metal. An unbuffed alodized finish accepts primer and finish painting.

anodizing by the chromic-acid process

The chromic-acid process is not suitable for aluminum alloys that contain more than 5 per cent copper, but it is fine for all other aluminum alloys. The chromic-acid process is especially recommended for anodizing assembly parts, particularly where inadequate flushing and rinsing of trapped sulphuric acid could lead to later problems. The films generated by the chromic-acid process are thinner than those obtained with the sulphuric-acid process, but despite their relative thinness, they are durable and offer a highly stable protective coating — from a corrosion standpoint especially.

The thinness of chromic-acid coatings is sometimes of value in manufacturing procedures, especially where ultra-close fits are involved and where matching is to be within sub-mill tolerances. The U.S. government specification MIL-A-8625A (December 14, 1954), which calls for 250-hour salt-spray resistance, authorizes the chromic-acid process for all aluminum alloys except those bearing more than 5 per cent copper. Although the chromic-acid-generated anodized finish is much harder than the untreated metal itself, only limited abrasion resistance is afforded by this process because of the extreme thinness of the film. Also, with the sulphuric-acid anodizing process, a greater porosity occurs, with increased dye take-up in the thicker coating.

For the purposes of the average amateur requiring the anodized film characteristics of hardness, durability, and acceptance of dyes, the sulphuric-acid process is preferable.

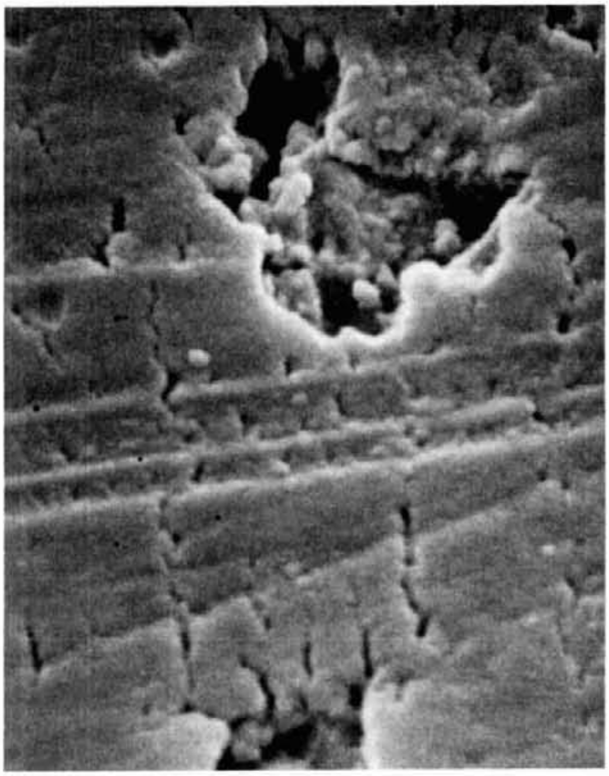
Three practical references,[1-3] supply details on the chromic-acid process for those rare applications where an amateur may need it.

aluminum alloys for effective anodizing

As mentioned, the qualities of the anodic film produced are affected significantly by the presence of other metals alloyed with the aluminum. Depending on the intended use of the aluminum, cost and availability may dictate which aluminum alloy is used, rather than the precise and sometimes subtle differences between the various alloys. The chemical differences between the various aluminum alloys can

*To get an idea of the magnitude of the dimensions involved, the following conversions are given:

1 micron	=	10^{-6} meter (3.94×10^{-5} inch)
1 Angstrom	=	10^{-1} millimicron or 10^{-7} mm (3.9×10^{-9} inch)
25.4 microns	=	2.54 (10^{-2}) mm (10^{-3} inch)
1 micron	=	10^4 Angstroms



Scanning electron micrograph (× 12,000), showing anomaly in anodic film probably caused by a carbon speck or other alloying constituent. Surface appears extremely smooth and lustrous, even under optical microscope inspection. Note that, even at 12,000 × magnification, molecular scale porosity can't be seen. Porosity is important in dye takeup of anodized parts. (Photo courtesy Dept. of Metallurgical Engineering, University of British Columbia, Vancouver, B.C.)

usually be found in the handbooks of large industrial suppliers of nonferrous metals.

In its purest form, aluminum is very soft and quite ductile. For most purposes, however, greater strength and hardness are required; thus high-purity aluminum is seldom used. Greater strength is achieved in two ways. Usually, the pure metal is alloyed with other metal elements, such as manganese, copper, silicon, iron, and magnesium. In addition, the alloy may be heat treated to give it even greater strength. The designation **T** plus a number after the 4-digit alloy number indicates a heat-treated alloy.

Aluminum of high purity, when anodized by the sulphuric-acid process, yields a completely colorless anodic film. This film can be left clear and sealed off, or dyed and then sealed off. The paler colors are more readily dyed into the anodic films generated on the surface of pure, nonalloyed aluminum. The more alloying impurities present, the greater the tendency toward a pale-green or pale-brown cast to the undyed anodic film. This is seldom a problem, unless matching of the various parts of a structure made from different alloys is desired.

When pale dyes are to be used, the original alloy must be considered, and the acid concentration as well as current density should be controlled for a thick film formation; *e.g.*, 15-20 microns or about 1.5 x 10^{-2} mm (6 x 10^{-4} inch), thus permitting greater dye take-up. The more concentrated the acid electrolyte solution, the softer and more porous the anodic film.

Experimentation is often required to achieve the required anodic film properties of a particular dye. A sample scrap piece of the alloy to be used can be processed in a trial run, thereby assuring more predictable results.

Of course, more predictable results can be obtained when alloys of known composition are used. Some alloys are better candidates for taking an anodic finish than others. For example, the well-known Alcan 6061 T4 and 6061 T6 take an excellent anodic finish. The finish will reflect absolutely and exactly the smoothness or roughness of the final machining operation.

Anodizing makes no noticeable difference to the texture of the aluminum. To see the finish (except for the color), even the strongest optical microscopes are useless. As discussed earlier, the scale being dealt with here is molecular; the transmission electron microscope is required to reveal the anodic film texture. Even with a scanning electron microscope (SEM) the porosity is invisible.

the sulphuric-acid process

First of all, aluminum anodizing should not be done indoors unless special ventilating equipment can be installed. Ideally, the anodizing workshop should be outdoors with plenty of air circulation; the ideal outdoor workshop is a home carport or garage with all doors open. If something approaching a chemistry laboratory fume hood with a spark-free extractor fan can be placed over the anodizing tank to exhaust the gaseous hydrogen emitted at the cathode, indoor anodizing may be possible. Remember that electrolytic dissociation breaks water down into two atoms of hydrogen for each atom of oxygen. Oxygen reacting at the aluminum-anode surface — allowing aluminum-oxide formation — causes the liberation of hydrogen gas at the cathode. This gas is emitted with a small amount of acid vapor from the electrolyte and is best vented outdoors, where it will be rendered harmless by mixing with air.

safety precautions

Small anodizing jobs in the home workshop can be

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done safely. The degree of hazard is similar to that of quick-charging an automobile lead-acid storage battery. The acid concentrations are roughly the same and the amount of discharged gaseous hydrogen is similar.

The major hazards are the effects of acid on skin or eye tissue and the risk of a spark's igniting hydrogen gas. Both hazards are avoidable. The golden rule of mixing acid is *always pour concentrated acid into the water — and slowly*! This allows the heat of the chemical reaction between the water and acid to be absorbed by the larger volume of water. If a sudden expansion of the smaller amount of acid should occur due to the rapid temperature increase that occurs on contact, it is water that is present in quantity, rather than the more dangerous acid. Once the 15-25 per cent solution of sulphuric acid is mixed, it then becomes the working electrolyte, in which the anodizing process takes place. After evaporation has occurred the tank can be topped-up safely by carefully pouring more water into the dilute solution.

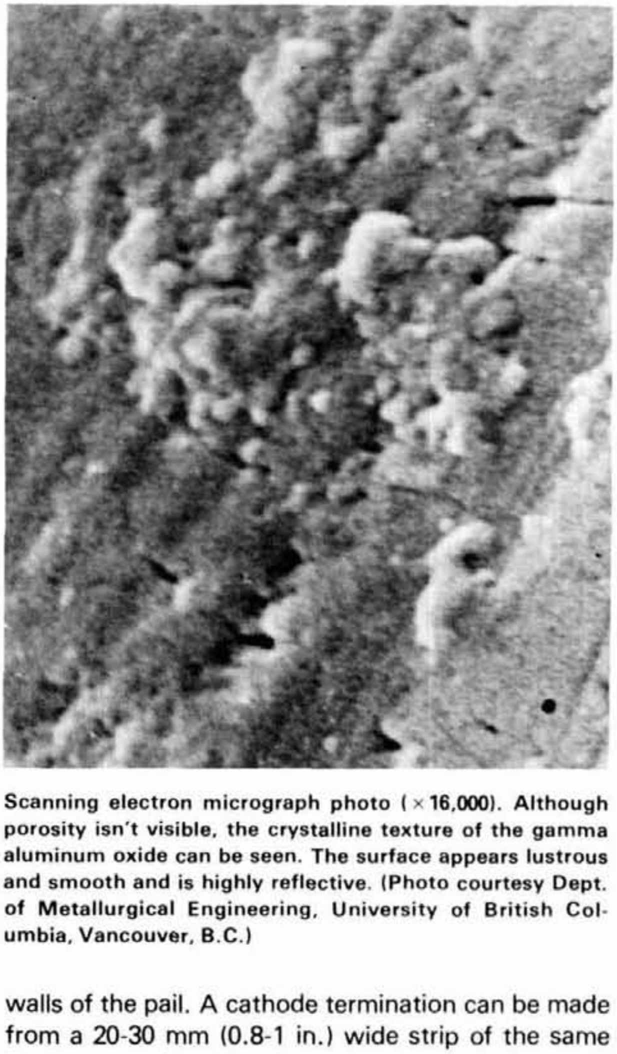
When mixing acid, immersing an item to be anodized, or removing it, wear protective clothing such as an apron made from a heavy fabric (canvas or rubber).

Use large rubber gloves to protect the hands and wrists, and acid-proof safety goggles over the eyes. Even a tiny splash of only a few milliliters of acid can cause serious damage to the eyes. If appropriate precautions are taken and the working area is clear and safe, the degree of risk is minimized. As with other procedures, human error, misjudgement, and carelessness (including too much speed) are most dangerous. Keep a pail of water handy!

the anodizing tank

The anodizing tank must be large enough to accommodate the lead cathode (which takes up very little space) and the largest article to be anodized. (If nothing larger than a thimble is to be anodized, the tank could be a plastic coffee cup, and the process could be done indoors with minimal ventilation.) *Most of the items anodized in my setup were small —* seldom larger than a dinner plate. The tank can be any container that's nonconducting and impervious to dilute sulphuric acid. A plastic pail, a hard rubber vessel, a glass tank (such as may be salvaged from a large lead-acid storage cell) or even a heavy plastic kitchen dish pan can be used.

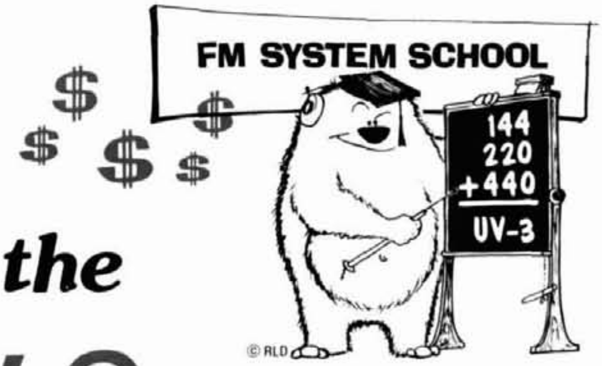
The cathode must be constructed of lead. If the tank is a polyethylene or hard-rubber pail, round or square, the cathode can be easily fitted from a sheet of plumber's lead. Cut a 1-3 mm (0.04-0.1 in.) sheet of lead so it can be rolled into a liner in the shape of an open-ended cylinder that can be placed inside the



Scanning electron micrograph photo (× 16,000). Although porosity isn't visible, the crystalline texture of the gamma aluminum oxide can be seen. The surface appears lustrous and smooth and is highly reflective. (Photo courtesy Dept. of Metallurgical Engineering, University of British Columbia, Vancouver, B.C.)

walls of the pail. A cathode termination can be made from a 20-30 mm (0.8-1 in.) wide strip of the same lead sheet, soldered to the upper edge of the cylindrical cathode, and extended up to the top of the tank. At that point, clear of acid contact, the lead can be soldered to a flexible length of 3.3 or 2.6 mm (no. 8 or 10) copper wire for connection to the negative terminal of the anodizing power supply. *The size of the* cathode, in surface area, must be at least equal to the area of the surface being anodized. The cathode in my tank covers the interior walls of the pail (20 liters, or 5-1/2 gallons) and extends the full depth of the acid contained in it when about two-thirds full. The bottom of the pail remains uncovered by the cathode so that some items being anodized may be set on the nonconducting tank bottom. The tank bottom could also be covered with lead, offering a larger surface-area cathode, but it would then be difficult to avoid contact with the bottom.

The electrolytic-tank anode pole is formed by using only aluminum, including aluminum screws, bolts, or other connectors, except for parts which no acid will contact. The item to be anodized can be fastened either by friction fit or by aluminum



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fasteners to an aluminum rod or strip and hung into the central area of the tank. A wooden slat or two across the tank top serves as a stabilizer for the central anode fixtures. Connection by aluminum fasteners to the item to be anodized should be made on some part of the item where it won't matter. The point of contact — where the anode connection is made — obscures a small area that remains unanodized.

acid concentration

The sulphuric-acid electrolyte used for anodizing should be between 15 and 25 per cent concentration by weight. The table below shows appropriate quantities of concentrated sulphuric acid for dilutions between 15 and 25 per cent by weight.

acid dilution (per cent)	concentration per liter (quart) of water
15	173 ml (5.9 oz)
18	212 ml (7.2 oz)
20	240 ml (8.2 oz)
25	310 ml (10.5 oz)

The plastic containers of sulphuric acid sold by automotive parts stores for filling new automobile storage batteries make an excellent source of acid for anodizing. Simply mixing the acid with water in a 1:1 ratio makes a good dilution for a working anodizing solution.

Minor impurities that occur in drinking water, mainly small concentrations of minerals and alkali, will have little effect on the anodizing results. The other metals in the aluminum alloy appear to play a more important role in determining the undyed color of the anodic film. If the water is especially alkaline, the resultant acid concentration obtained by the table may give lower actual concentrations due to neutralization.

power supply

The power-supply capacity that will be needed is determined by the size of the aluminum items to be anodized. The current density required in the sulphuric-acid process averages 1.5 amperes per decimeter^2 (3.4 inch^2) of surface area of the item to be anodized. However, the current density will vary in relation to several factors:

1. Acid concentration
2. Voltage potential between anode and cathode
3. Electrolyte temperature

The voltage potential is not critical, although the softer and more porous films are generated at the higher voltages and current densities. Any voltage between 6 and 20 volts will generate an anodic film, but 16-18 volts appears to be optimum when working with electrolyte temperatures between 18 and 22 C (66 - 72 F). The power supply must be able to produce full-wave direct current, not necessarily filtered, of 18 volts and 30-50 amperes for periods of about an hour without overheating.

Ordinarily the voltage is preset. Current flow will then be determined by acid concentration, temperature, and the surface area of the item to be anodized. A voltmeter and ammeter are helpful. Current flow does not decrease with anodic film buildup as in the chromic acid process.

operating conditions

Anodizing can be done with the electrolyte at a number of different temperatures.

When the electrolyte is started at room temperature ($\approx$20 C, or 68 F), after several hours of anodizing a rise in electrolyte temperature can occur. This increase varies with the size of the items being anodized and the current flow through the electrolyte. As the temperature rises, the anodic film will be softer and more porous — which makes for better dye takeup — but the film will have a reduced hardness. The tank can be left to cool at this point. Sometimes the rise in electrolyte temperature is acceptable, especially when extreme hardness is not necessary and when the dark-colored dyes, such as black or deep blue, are being used.

If accelerated electrolyte cooling is required (seldom necessary in most amateur setups), the cathode could be constructed of lead tubing, with a suitable coolant pumped through it, thus permitting the electrolyte temperature to be thermostatically controlled.

Anodic-film porosity is controlled by acid concentration, current flow, and voltage, all of which are interrelated. Film thickness, however, is controlled by the length of time of film generation. Some experimentation will demonstrate more exact times and there is some latitude in this variable; but generally two categories of time length apply: if the anodic film is not to be dyed, about 15-25 minutes is usually ample. If the film is to be dyed, however, and especially with the dyes requiring a high degree of film takeup, periods in the range of 45-60 minutes should be used. Different alloys will require different times, even when all other variables are held constant, including voltage, current density, electrolyte temperature, and electrolyte concentration.

sealing

The anodic film generated in the electrolyte is gamma aluminum oxide. The molecular porosity of this oxide and its extreme hardness are desired characteristics. If the surface is not to be dyed, however, it will offer greater permanence to its uniform coloration if it is converted to the nonporous boehmite. This conversion is easily made by immersing the rinsed and clean anodized item in boiling water for about 20 minutes.

If the anodic film has been dyed, the sealing process of simple immersion in boiling water can cause dye leaching. To avoid this, chemicals are added to the sealing solution, usually a low concentration of nickel acetate in water held at 95 - 98 C (203 - 208 F). The sealant chemical may vary depending on the dye. I've never required an antileaching agent, since a small amount of leaching has been tolerable.

dyeing

Commercial procedures for the uniform dyeing of anodized aluminum can be complex and expensive. One of the most critical factors is the *pH* of the dye solutions and sealant solutions.

The purpose of anodizing an aluminum surface, aside from increased durability and hardness, is to produce a porosity that will allow dye to penetrate. As mentioned, however, the porosity formed from the anodizing process is on a molecular scale. Unlike dyes used for cloth, where absorption of dye is an easy matter because of the large pores in the fabric, dyes capable of takeup by an anodized surface must have molecular constituents small enough to fit into the pores in the film surface. Many ordinary dyes that permanently stain ordinary fabrics have no effect whatsoever on the more subtle porosity of anodic films. For this reason, special dyes have been developed.

In North America, two large suppliers of commercial dyes and supplies for the anodizing industry are Sandoz* and the Allied Chemical and Dye Corporation.† Chemical dyes available from them come in about 50 different colors. If a more limited selection of dyes can be accepted, some ordinary, inexpensive fabric dyes sold in drugstores will prove satisfactory for anodic film takeup if a few special measures are taken. Wool dyes must be selected, rather than those only for cotton or other fibers. The *pH* must be controlled and the concentration must be higher. Usually about 25 grams/liter (0.9 oz./qt.) of the solute, with the addition of about 1 ml/liter (0.03 oz./qt.) of acetic acid (vinegar), will yield reasonable coloring results. Certain dyes, because of their large molecular size, will be unusable. However, after experimentation, you may find that many different dye colors can be used at a fraction of the price of commercial anodizing dyes. The golds and blues tend to be most effective, some without the addition of acetic acid.

For the most effective dye takeup by a well-generated anodic film, heating the dye solution to 55 - 75 C (131 - 167 F) is required. The dye takeup won't increase after about 10-15 minutes immersion in the heated dye. Different dyes take up at different temperatures; experiment to find the optimum values.

Very dark black anodic dye will probably have to be purchased from one of the commercial dye sources or from an anodizing shop. Commercial anodizing dyes are extremely powerful, so only a small amount will be required.

After repeated use the dye will become gradually acidic from acid leaching out of the anodized surfaces, even though these surfaces have been carefully rinsed. At this stage the *pH* of the dye solution must be restored by adding small amounts of alkali, usually lye solution. If the inexpensive drugstore fabric dyes are used, an alternative to fussy *pH* control is to replace the acidic dye with a fresh mix of new dye, a practice that has been acceptable in my experience.

summary

Anodizing aluminum is an exact science. For the amateur in the home workshop it may be an art that requires much experimentation before you develop consistent results. But anodizing offers many advantages over other protective coatings and yields a permanent and stable finish for aluminum.

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*Canada: Sandoz Colors and Chemicals, Box 385, Dorval, Quebec H9R 4P5. U.S.A.: Sandoz, Inc., 608 5th Avenue, New York, New York 10020.

†Allied Chemical and Dye Corporation, Industrial Division, 1348 Block Street, Baltimore, Maryland 21231.

simple CMOS keyer

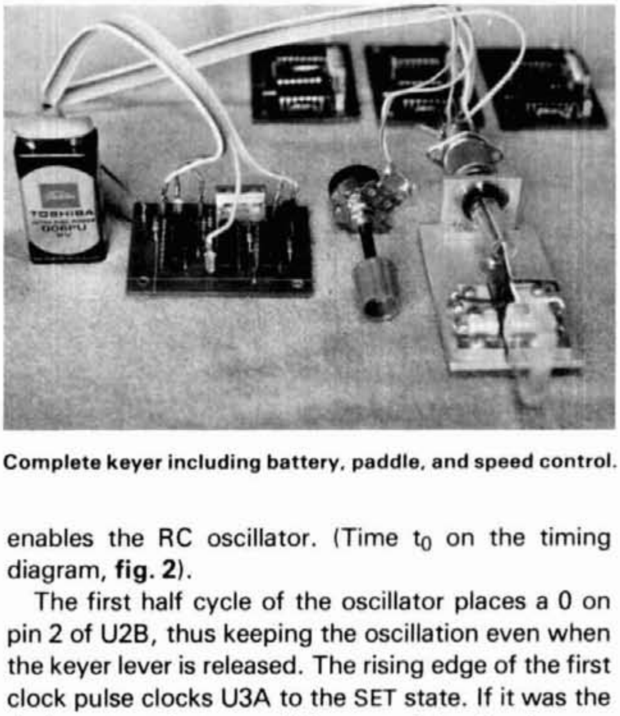
Build this simple, low-cost CMOS keyer for inclusion in any battery-powered equipment

The construction of this keyer is a result of an effort to reduce the overall weight of my "Mountain Day" contest transceiver. The circuit was developed from a proven RTL design. Although it does not offer "squeeze keying" or dot/dash storage, it fits the needs of the beginner as well as of the high-speed brass pounder.

The dash/dot ratio remains exactly 3:1 over the whole speed range. After each dot or dash, a pause of exactly one dot length is inserted. When both dot and dash contacts are closed, dashes are sent. With a 9-volt power supply, keying current is about 2 mA. When the keyer is not being operated, only about 10 nA is drawn from the supply; you may therefore connect the battery at all times and forget about the ON/OFF switch. The keying transistor switches positive voltages to ground. Changes in supply voltage have no appreciable effect on the speed. When the circuit is mounted and adequately shielded, it is not susceptible to rf pickup — even without rf chokes and bypass capacitors.

circuit description

The schematic diagram shown in **fig. 1** is divided into two main parts, the time base and dot/dash generator. The time base, a stable RC oscillator is composed of gates U1A, U2A, and U1B, plus the associated components. Dot flip-flop U3A, dash flip-flop U3B, and the summing gate U2C form the dot/dash generator. In the quiescent state, these are the logic levels: logic 1 on pin 9 of U2D (due to the AND gate formed by R5, R6, CR1, and CR2) and both flip-flops reset, providing a 1 on pin 10 of U2D. U2A and U2B form the control flip-flop for the oscillator, which is blocked by the zero from pin 3 of U2B. After a short closure of either the dot or dash contact, U2B



Complete keyer including battery, paddle, and speed control.

enables the RC oscillator. (Time t_0 on the timing diagram, **fig. 2**).

The first half cycle of the oscillator places a 0 on pin 2 of U2B, thus keeping the oscillation even when the keyer lever is released. The rising edge of the first clock pulse clocks U3A to the SET state. If it was the dash contact that caused the start of the time base, a 1 from U1C would release the J input of U3B, allowing this flip-flop to be triggered by the rising edge of

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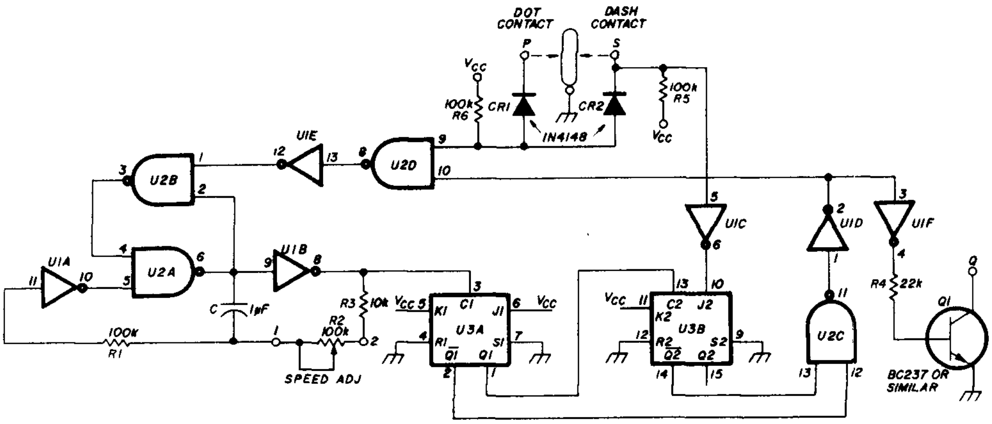


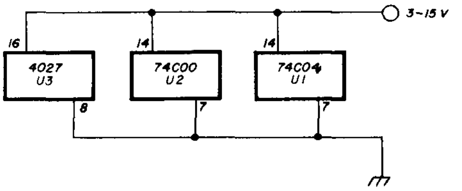


fig. 1. Schematic diagram of the simple CMOS keyer. The speed control, R2, should have a reverse, log taper. The keyer will work with any battery supply between 3 and 15 volts. External connections are denoted by the circled terminals.

U3A's output. In case of a dot contact closure, U3B remains reset because the zero on its J input prevents it from toggling.

The outputs of the flip-flops are summed by U2C, state. When U3A toggles back to the RESET state, the dot or dash is terminated. At this time (for dots t_1; for dashes, t_2) the clock signal is a one, maintaining oscillation for another half clock period. At this

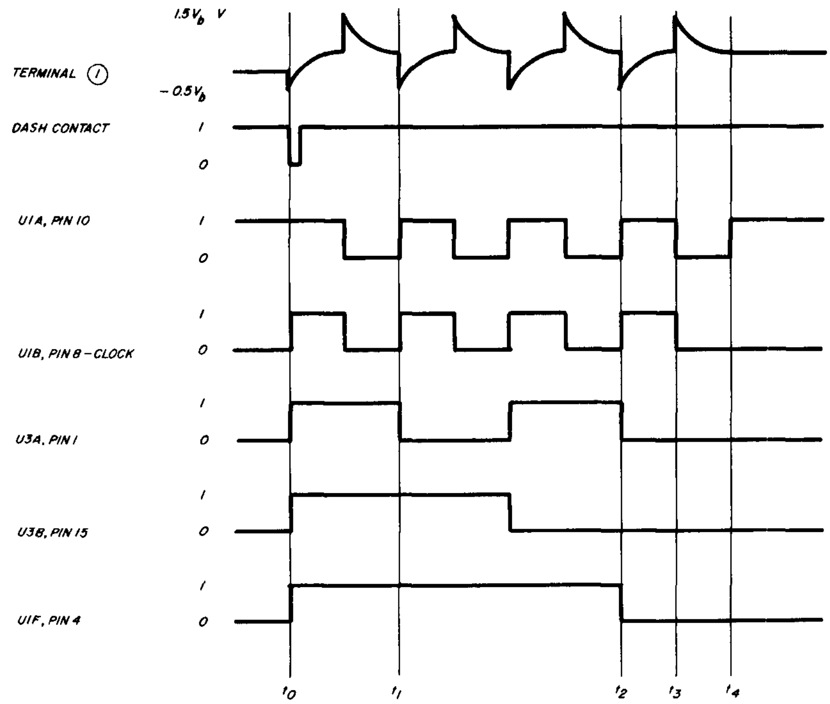


fig. 2. Timing diagram showing the levels within the keyer during the generation of a dash.

and via the inverters drive the keying transistor. The keying signal is fed back via U2D and U1E to the control flip-flop. As long as a dot or dash is being sent, this flip-flop maintains the oscillator in the operating time (t_3) the voltage at terminal 1 is 1.5 V_{batt}, which via U1A places a zero on U2A, thereby preventing the control flip-flop from reacting to premature trigger signals. After another half dot length, the voltage

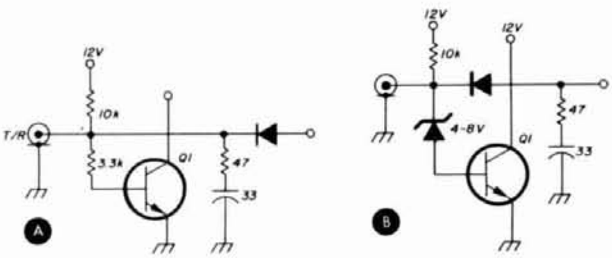


fig. 3. The diagram of the original keying circuit in the Ten-Tec Argonaut is shown in A. To handle the saturation voltage of semiconductor keyers, the circuit was changed to the configuration shown in B. The value of the zener diode can be between 4 and 8 volts.

at terminal 1 of C has discharged to almost 0 volts. This level is transferred by U1A, as a logic 1 to the control flip-flop, which, while maintaining state, can now be triggered again by signals from the keying contacts. After this pause of one dot length, (t_2-t_4), the circuit is again in the quiescent state and ready for another dot or dash.

transmitter connections

Due to its small size, the keyer circuit can easily be built into virtually any transmitter or transceiver. However a word must be said concerning the keying circuit involved. The voltage to be keyed must be positive with respect to ground. It must not exceed the voltage blocking capabilities of the keying transistor and the keyed current must be within the limits of this transistor. The keying circuit should support keying by semiconductors; with a voltage drop of up to 1 volt across the KEY terminals, the circuit must still operate properly. With a TenTec Argonaut, this was not the case, although a minor modification according to **fig. 3** solved the problem.

Transmitters with a negative-keying voltage must be modified to have a positive keying voltage. Compatibility with straight keys or relay keyers is, of course, not impaired by such a modification. **Fig. 4** shows the modification of a Heath HW101 as a representative of the tube transmitter family. Here are some general hints for this kind of modification: the voltage divider, R7, R8, and R9, must be set up to accept a current in the range of 0.5 to 10 mA. The internal resistance of the positive and negative sources must be taken into account when the values of the resistors are determined. With the key open, the voltage at the base of Q1 may not exceed V_{EB} maximum (4 to 8 volts, depending on Q1). With the key down, the voltage between R7 and R8 (base of Q1 not yet connected) should be substantially more negative than the 0.7 volts needed to completely drive Q1 into saturation.

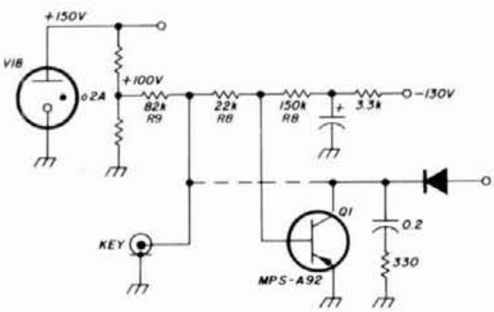
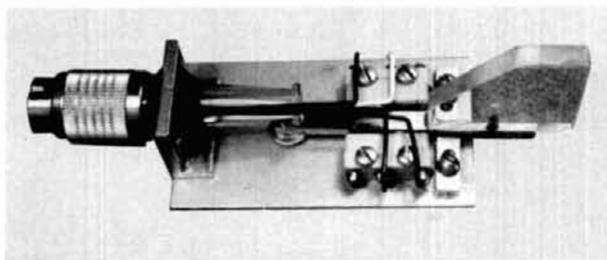


fig. 4. Diagram of the keying circuit of an HW101 that has been modified for this keyer. Other than R7, R8, R9, and Q1, all other components are from the original circuit.



Paddle mechanism used by the author with his Mountain-Day transceiver. Microswitches are used as the contacts.

Although the original purpose of this keyer circuit was incorporation into small transceivers, nothing prevents you from using it as an external electronic key. The use of a reed relay or an opto coupler in the output circuit would render the keyer more versatile (at the expense, however, of considerably higher power consumption).

construction

Circuit layout is not critical. An example of a printed circuit board layout is shown in **fig. 5***. Be careful to use a polyester (or equivalent) timing capacitor. The leakage current of tantalum and aluminum electrolytic capacitors is not compatible with the high-impedance CMOS logic. In the most commonly used speed range, R2 has a value of between 3 and 30 kohms. A potentiometer with a negative logarithmic characteristic would therefore be ideal. A standard 100-k logarithmic pot may be used instead, but the turning direction for an increase in speed would be counter-clockwise. If you insist on clockwise direction, a 100-k linear pot will do the job even if speed adjustment isn't best.

*An etched, drilled, and plated printed circuit board is available (air-mailed to the USA and Canada) from the author for 10 sFr (USA $5.00).

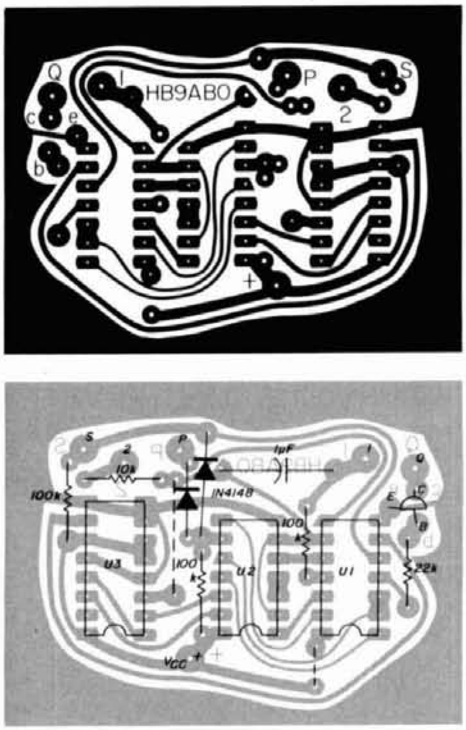


fig. 5. Printed circuit board layout of the simple CMOS keyer, with the parts placement diagram shown below. The two dashed lines indicate jumpers that must be installed.

the paddle

An example of a lightweight portable paddle is shown in the photograph. The unit is connected to the transceiver by a 3-pin DIN plug whose shell is screwed to the socket in the rig. The brass lever measures 60 × 3 × 5 mm (2-3/8 × 1/8 × 3/16 inches) and is centered by the buttons of two micro switches. It is fixed to the bottom plate at the pivoting point. The lateral movement is limited by two small aluminum blocks whose distance from the lever is adjusted to allow the lever to move just slightly beyond the switching points. Although there might be more elaborate solutions to this problem, the unit has worked nicely for over a year.

Further ideas for a portable keyer paddle can be found in **ref. 3** and **4**, the latter being more promising according to the rule *the simpler the better*.

references

1. Richard P. Halverson, WØZHN and Ronald A. Stordahl, KØUXQ, "An Integrated-Circuit Electronic Keyer," *QST*, April, 1968, page 22.
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3. Gene Hinkle, WA5KPG, "Ideas for a Portable Keyer Paddle," *ham radio*, February, 1977, page 52.
4. Vidi la Grange, ZS6AL, "Simple Paddle for Electronic Keyers," *ham radio*, April, 1978, page 28.

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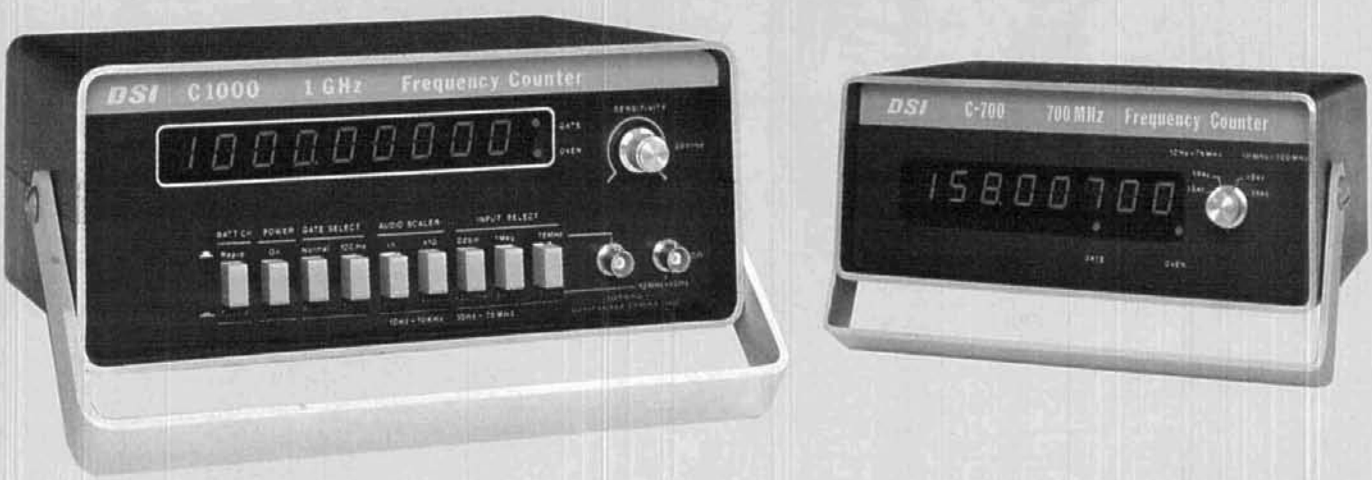

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3600A	50Hz - 600MHz	Oven .5 PPM 17° - 37°C	10MV	10MV	50MV	8	.5 Inch	115VAC or 8.2 - 14.5VDC	2⅛"H x 8"W x 5"D
3550W	50Hz - 550MHz	1 PPM 65° - 85°F	25MV	25MV	75MV	8	.5 Inch	115VAC or 8.2 - 14.5VDC	2⅛"H x 8"W x 5"D

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DIGITAL TECHNIQUES

digital techniques basic rules and gates

Digital circuits are a useful and fascinating part of today's electronics. Devices and their applications have increased by such a proportion that an amateur who is not employed in the electronics industry may be confused by the jargon surrounding the technology. This series of articles will present the basics and, it's hoped, give you an insight into practical applications.

We are familiar with linear or "analog" circuitry, but what is a digital circuit? It is simply a decision-making device based on two voltage levels per input. The output also has two voltage levels. A two-valued input and output is called *binary*.

Digital circuitry (or, *digital logic*) is made from simple building blocks which obey specific logical rules. Interconnection of many simple blocks is possible, whether on a circuit board or a single chip of silicon. Modern technology allows an almost unlimited combination on a single chip, spawning hundreds of different digital devices. Despite their complexity of function, all digital devices are made from the basic blocks.

Several digital families exist. Differences are internal and have an effect on interfacing. The two largest families will be described: TTL or Transistor-Transistor-Logic, the *bipolar* family branch, and CMOS or Complementary-MOS, the fet branch. Interconnection between families is possible within certain rules.

By Leonard Anderson, 10048 Lanark Street, Sun Valley, California 91352

logic level reference

Binary levels must be defined. A *low* level is near ground. A *high* level is close to the supply voltage. Some fet digital devices have more than one supply, so these refer the high level to the "V_{CC}" supply. The high level is assumed more positive, relative to ground or common.

Logic levels may be *positive* or *negative*. Positive logic is most common and retained throughout this series. Levels have different descriptions, so it might be well to memorize the following:

Low = *0* = *near-ground* = *logic 0* = *false*

High = *1* = *positive* = *logic 1* = *true*

Low, high, 0, and 1 are the most common terms. True and false may apply to devices with double outputs, one being an inverted level of the other.

A few data sheets refer to negative logic. This is generally taken as just a voltage reversal, although low and high are still the same.

basic building block

This is the gate, the fundamental decision maker. Each gate may have any number of inputs, but only one output. The six basic gates are shown in **fig. 1** along with an inverter. The latter has only one input and is used mainly for level inversion.

Input states, for a specific output, will determine the type of gate. Note the small tables of 1s and 0s for each gate. These are *truth tables* and tell the most about a particular function. Truth tables exist for circuits and all device types; some are time dependent.

The AND gate output will be a 1 when both A *and* B inputs are 1. All inputs of a multiple-input gate would have to be 1 for a 1 output. The OR gate output will be 1 when *any* input is a 1; output is 0 only when all inputs are 0. Exclusive-OR gates have only two inputs; a 1 on either input will produce a 1 output. But a 1 on both inputs will output a 0.

NOT, NAND and NOR

Compare the truth tables of the AND and NAND, OR and NOR, and the Exclusive gates of **fig. 1**. Each pair, of the three types, will have opposite output states. All six types are needed for design flexibility, but the NAND, NOR and Exclusive-NOR may be confusing.

Digital technology uses the term "not" when a desired signal is low; *i.e.*, it is not high. A line named SIGNAL would be considered active (desired) when high. Renaming it $\overline{\text{SIGNAL}}$ with the overbar means it is active when low. The name $\overline{\text{SIGNAL}}$ is pronounced "signal not" or "signal bar," and either form is used.

A NAND gate output is active low. Its name comes from "not-AND." A NOR gate output is active low; its name is "not-OR." Similarly, an Exclusive-NOR is active low.

Symbol shape and little circles describe the type. Shape denotes general function while the circle or "inversion bubble" indicates an active low input or output. The bubble isn't always shown on spec sheets, so check for a device pin, name overbar, or the truth table.

The uses of NAND and NOR gates may not be apparent, so let's examine some simple gate arrays. The function of the array in **fig. 2** is to provide a high output when the inputs from either A and B or C and D are high. For ease of illustration, C and D are kept low. Intermediate AND output states E and F may not be used but are good for following an array function.

the ubiquitous NAND

The array in **fig. 3** performs the same function as the one in **fig. 2**, even though all gates are NANDs. The equivalent OR function has bubble inputs, matching the active low NAND outputs. If this is confusing, go back to **fig. 1** and check the state conditions of NAND input versus output. Intermediate states E and F are useful here.

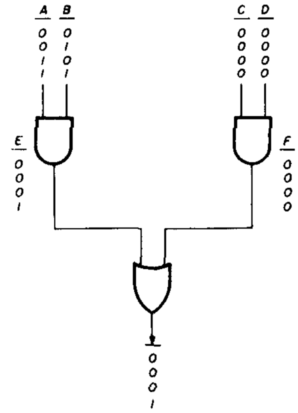

fig. 2. Conventional AND/OR gates can be combined to produce the desired outputs. In this example, a 1 output will be present when A and B, or C and D are both 1s.

NAND gates can be used for any equivalent AND-OR array cascade. Most TTL gate arrays are built up entirely of NANDs and came about through early all-transistor logic circuits. Economy in earlier days dictated a minimum number of discrete devices and resulted in inverted outputs. Designers found that all-NAND gate array cascades worked just as well as older diode gates. The first integrated circuit gates used equivalent NAND structures.

NANDs are now so numerous that an unofficial "NAND RULE" is used to analyze and design gate arrays.

> THE NAND RULE: *Any* low input will cause a high output state; *All* inputs must be high to cause a low output state.

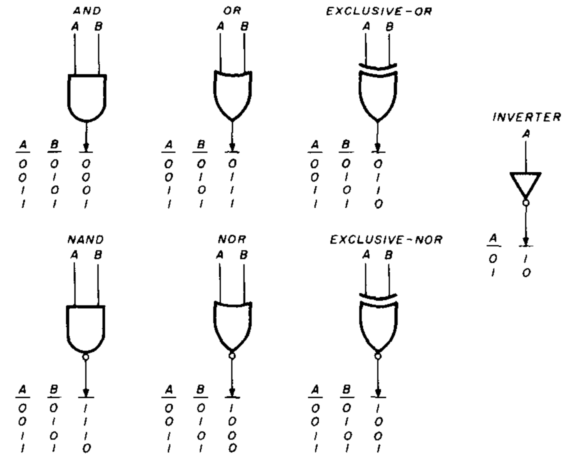

fig. 1. Schematic symbols and truth tables for six basic gates, AND, NAND, OR, NOR, Ex-OR, and Ex-NOR, and the inverter.

NAND gates used for an AND function will have active high inputs, just like an AND. The equivalent OR function requires active low inputs. Direct equivalents are shown in **fig. 4. Fig. 4B** is the same as an AND, while **fig. 4A** is the same as an OR. Inverters take care of necessary input and output state changes.

Fig. 5 is a simple array which produces a high output when either A and B are high or $\overline{C}$ input is low. Note that the overbar indicates $\overline{C}$ is active low. If conventional AND-OR gates were used, you would have C with an active high. This array shows an interesting input control condition.

Holding $\overline{C}$ low will prevent both A and B from affecting the output. Inputs A and B could then be in any state combination and the output truth table would indicate them as *don't care* states. Since they cannot affect the output, you don't care what states

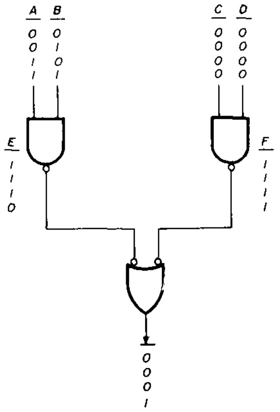

fig. 3. In this example, the AND/OR gates of fig. 2 have been replaced by NANDs and NORs. Even with the change, a 1 will be present at the output for the same input conditions.

they are in. An "X" on the truth table indicates the don't care condition.

When low, the $\overline{C}$ input can be considered an inhibit for A and B. Conversely, it could be an enable input when high. Many multifunction devices have inhibit and enable inputs. A word of caution: Inhibit and enable controls may be active high or low; check the device spec sheet for bubbles and overbars.

TTL and CMOS families

TTL is the most common family. It was pioneered by Texas Instruments, and wide industry acceptance prompted all major semiconductor manufacturers to "second source" (make the same product under license) most or all devices in the original family. Their popularity resulted in other IC makers' designing their own TTL devices; TI "second sources" many of these.

TTL is sometimes referred to as the 54/74 Series, after TI's original numbering scheme. TI now uses an SN prefix, while other makers have different prefixes. The "54" or "74" number identifies the device. A 7400 package is a quadruple two-input NAND gate, regardless of source. Many parts lists omit prefixes, since second source devices have identical characteristics.

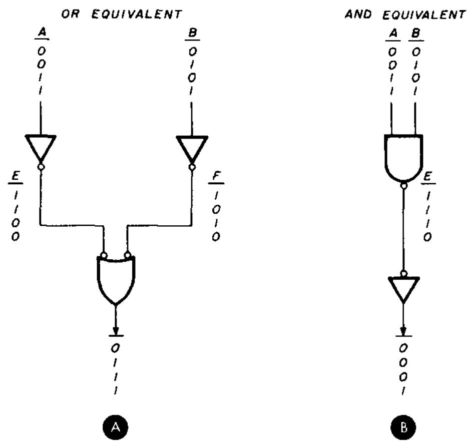

fig. 4. In A, since the NAND gate can be represented by an OR gate with inverters or the input, the complete OR function can be duplicated by using a NAND gate with an inverter in each input. B shows the AND equivalent by using a NAND gate with an inverter on the output.

A "54" part is military temperature grade, −55° to +125°C. A "74" part is commercial or industrial grade, with an operating range of 0° to +70°C. There is a slight difference in operating characteristics, but this would rarely affect amateur equipment.

CMOS is the most common fet family and is ideal for low-power applications. Where TTL has internal bipolar transistors, CMOS has N-type and P-type MOSFETs in complementary arrangements. The MOSFETs are insulated-gate types with extremely high input impedance.

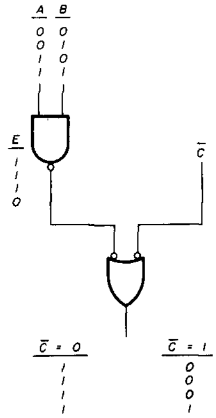

fig. 5. The C input, in this case, can be used as a circuit inhibit. If low, the output will always be high, regardless of the A or B inputs. When C is high, then the output will be enabled and will respond to the other inputs.

RCA developed CMOS and uses a 4000 Series numbering system with a CA prefix. CMOS is also second-sourced, but part numbers for equivalents vary; cross-reference tables are required for most second sources.

CMOS military temperature is the same as TTL, but CMOS industrial-grade temperature is −40° to +85°C. CMOS is also more lenient in power-supply voltage. TTL requires +5 volts ±5 per cent, while CMOS supply voltages can vary from 3 to 15 volts! One pays a price for such tolerances; the same device will be slower at lower voltages.

RCA also introduced "B" series CMOS (suffix to number) as an improved version of their original "A" series. The B series incorporates output buffers for driving lower loads and is characterized at 5-, 10-, and 15-volt supplies. All new designs are in the B series.

The next article in this series will take a *detailed* look inside the devices to point up differences between TTL and CMOS.

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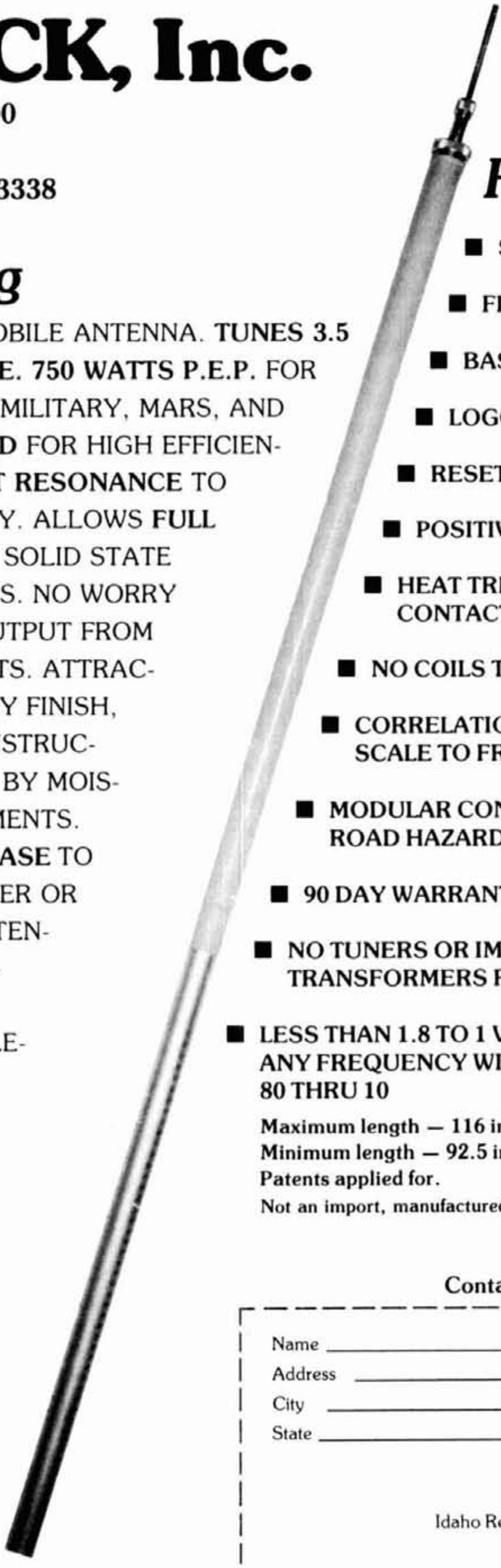

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the ham notebook

dual-impedance headphones

The switching arrangement is shown in this view of the dual-impedance headphones. Photo by WD9CXG.

Dual impedance headphones offer versatility, convenience, and private listening pleasure. With different types of receivers available on the market today, it is not unrealistic to have a ham-bands-only and a general-coverage receiver in the shack. In some instances, especially with older military equipment and newer ham gear, different impedances will exist at the headphone jack. This being the case, in order to have private listening, two headphones with different impedances were required (one for each rig). Thus, the need for a single pair of dual-impedance headphones.

Taking into account that the main source of audio was the amateur receiver (Kenwood TS-820), monaural 8-ohm headphones were purchased. The desire to listen to a military general coverage receiver meant switching headphones to provide the 600-ohm load specified in the manual.

It was not totally unrealistic to employ one pair of phones and change the impedance as desired. This was accomplished by placing a 600-to-8 ohm audio transformer in the line, switching it out for the 8-ohm load. If the components are carefully chosen (for size) they will all fit neatly into the housing of one of the phones, eliminating any external boxes. To prevent possible trouble, two double-pole, double-throw miniature toggle switches were used to completely isolate the transformer from the line.

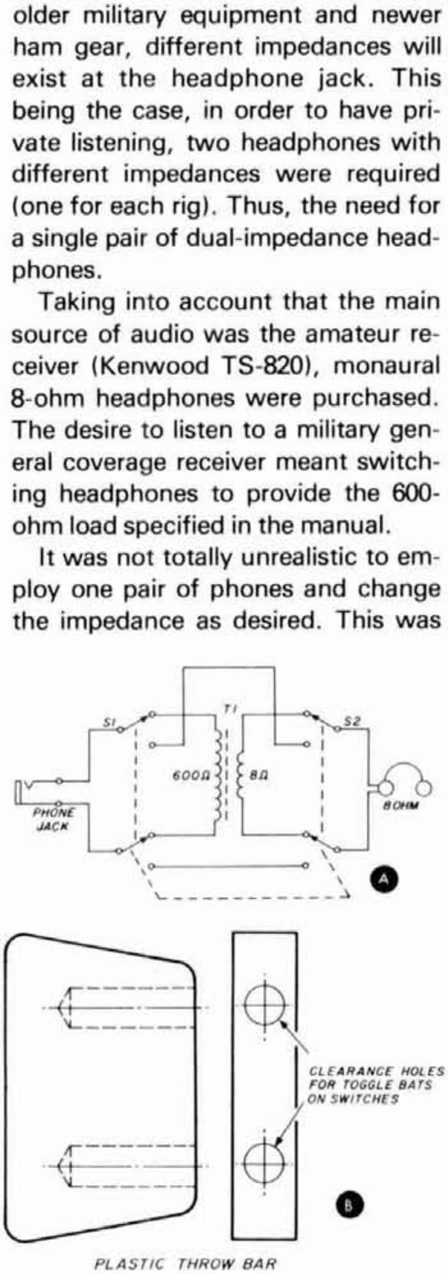

fig. 1. The schematic diagram in (A) shows the connections between the switches and audio transformer. T1 is a Calectro D1-724, having a 1200-ohm, center-tapped primary with an 8-ohm secondary. The switches can be ordinary miniature double-pole, double-throw switches. The small plastic throw bar is shown in (B). This bar can be shaped to fit any particular pair of headphones.

A plastic bar was used to throw both switches at the same time. Shaped into a design of your own choosing and drilled for clearance of the bats on the switches, a drop of epoxy will hold the "throw bar" in place. Before final insertion of the bar onto the switch bats, make sure both switches are thrown in the same direction.

Jim DiSpirito, AB9Q

HW-2036 antenna socket

The antenna socket on the rear of the Heath HW-2036 2-meter transceiver is directly in line with a trace on the final amplifier printed circuit board. This line, which connects pin 10 on the relay and pin 2 on the plug P301, carries 13.8 volts. When using a phono plug with the long center pin, this pin will touch the board, shorting the 13.8 volts to ground. It's best to use either the RCA or Motorola style plug, since they have a shorter center pin. The phono plug/PL-259 adapter sold by Radio Shack also has the long center pin, requiring that part of it be cut off to prevent it from contacting the circuit board. However, if you wish to take the time to disassemble the transceiver, a small piece of electrical tape can be placed over the trace to prevent accidental contact.

Jim Conner, W3HCE

improved tuning on 160 meters with the T-4X transmitters

When using either a T-4XB or T-4XC transmitter below 1850 kHz, a true dip could never be obtained and loading was difficult, even when using a 50-ohm dummy load. Through discussions with other Drake owners, I found that this frustrating problem was shared by other T-4X-series transmitter owners. Being curious about this strange behaviour, we called Drake only to find that their low-end cutoff frequency is 1840 kHz. With this news, we decided to optimize the output network for the 1800-1850 kHz band, since that's all we have in New England. The modifications are almost trivial, requiring only two capacitors in the output network and a third for the driver tank circuit, but the results are excellent. The transmitter can be loaded and controlled on the low end of 160 just the same as on any other band.

As shown in **fig. 3**, the modification to the output network requires the addition of a capacitor on each side of the pi network. The part numbers in parentheses apply to the T-4XC; the others, to the T-4XB. Using the pictorials provided in the Drake manual, locate S4H and C65 (C86). Add a 120-pF, 2000-volt capacitor in parallel with C65 (C86). Next, locate C67 (C89), an 865-pF capacitor on S4G, and add a 680-pF capacitor in parallel.

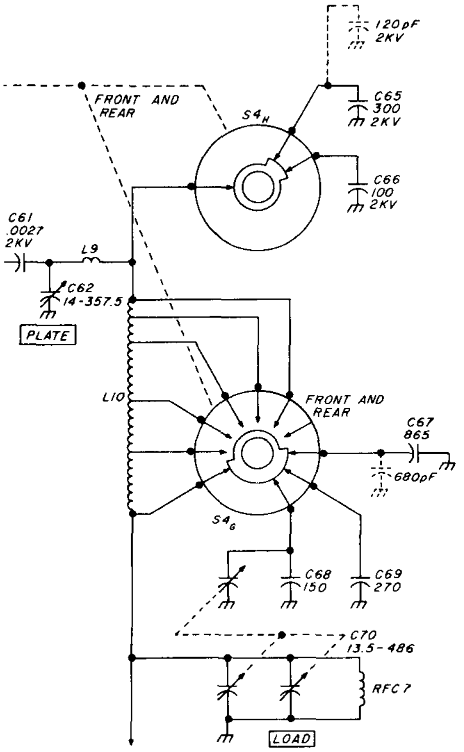

fig. 2. Schematic diagram of the changes made to the pi network to enable it to cover the low end of 160 meters. The numbers in parentheses refer to the components in the T4XC. The first designation is for the T4XB.

In addition to the output pi network, the driver tank circuit also required padding, since the driver control had to be rotated fully counterclockwise. This modification is depicted in **fig. 4**. A 36-pF capacitor was connected in parallel with C39 (C54), located on the rear of S4F.

With the implementation of these simple and inexpensive modifications, our Drake transmitters will load very nicely in the 1800-1840 kHz region, with the driver control showing a nice peak rather than being fully against the stop.

Steven E. Holzman, W1IBI
John D. Adamson, W1HZH

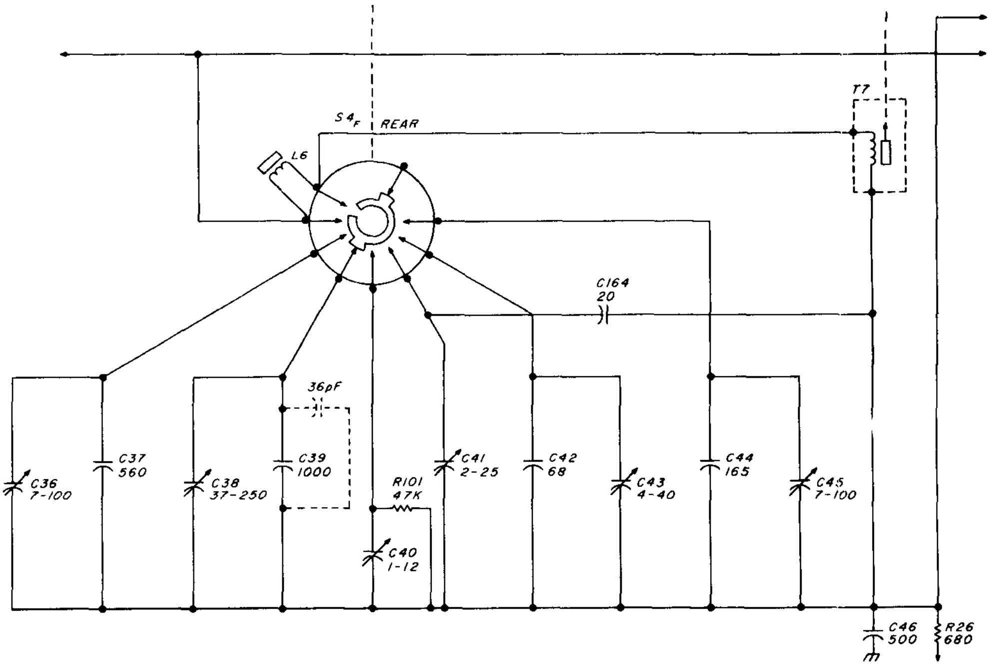

fig. 3. Changes made to the driver network for low end coverage of 160 meters.

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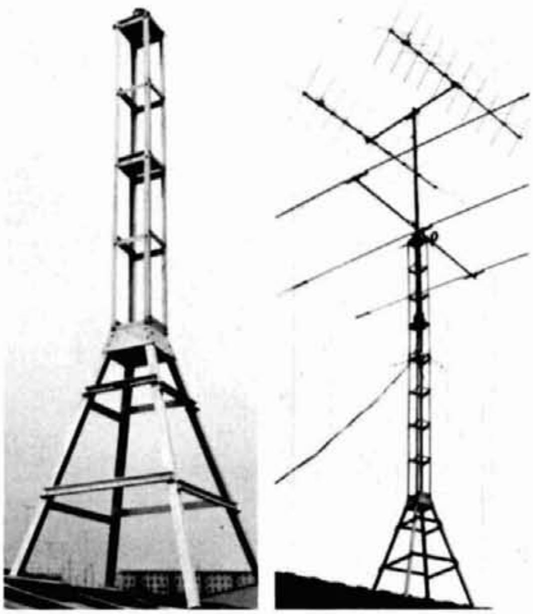

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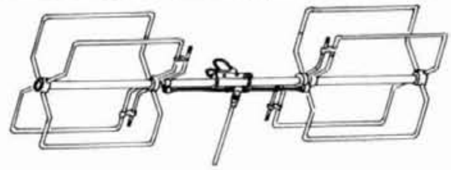

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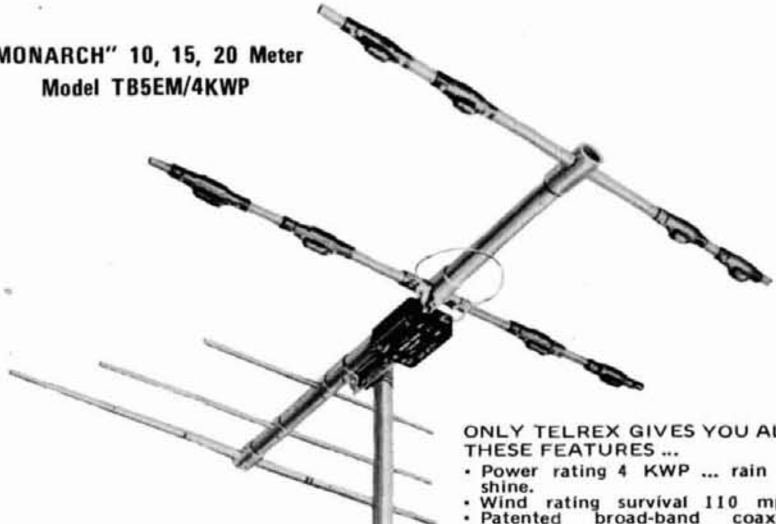

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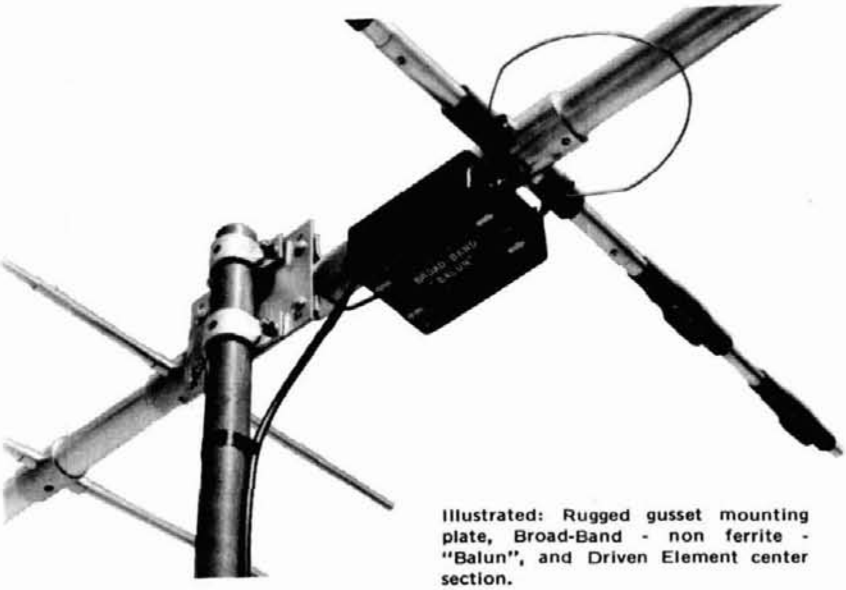

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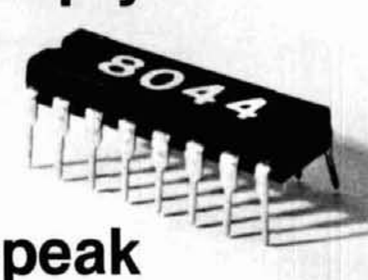

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More Details? CHECK—OFF Page 118

YOU ASKED FOR IT
YOU GOT IT
DSI
QUIK-KIT®

550 MHZ COUNTER KIT

Performance You Can Count On

OPERATES ON

- Batt 6-C Size
- DC 8.2 To 14.5 VDC
- AC Batt. Eliminator

$99.95

MODEL 3550 KIT

DSI OFFERS THE BEST OF TWO WORLDS . . .
An unprecendented DSI VALUE . . . in a high quality, LSI Design, 550 MHZ frequency counter kit. And, because it's a DSI innovation, you know it obsoletes any competitive makes, both in price & performance. The basic 550 MHZ counter & time base are factory assembled, tested and burned-in. The problems of bad LEDS, IC's, capacitors, are a thing of the past with DSI QUIK-KIT®. But you can take pride in assembling the power supply, PC mounted selector switch, input connectors, and the final mechanical assembly of your 550 MHZ counter, into its' handsome cabinet. **GO WITH THE LEADER . . . BUY A DSI FREQUENCY COUNTER KIT. SAVE TIME & MONEY AND BE ASSURED IT WILL WORK THE FIRST TIME.**

SEE YOUR LOCAL DEALER
OR
CALL TOLL FREE (800) 854-2049
Californa Residents, Call Collect (714) 565-8402

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CK • MONEY ORDER
COD

DSI INSTRUMENTS, INC.
7914 Ronson Road No. G, San Diego, CA 92111

SPECIFICATIONS

Time Base TCXO 1PPM 65° to 85°F
Frequency Range 50HZ to 550MHZ
Resolution 1HZ to 55MHZ, 10HZ to 550MHZ
Gate Time 1 second - 1/10 second
Sensitivity 25MV 150 & 250MHZ 75MV 550MHZ
Display Eight 1/2-inch LEDS
Input Two SO239 Connectors
Power 6C-Size Batt., 15HR, or 8.2VDC to 14.5VDC
Current 150 Ma standby 300 Ma operational

3550 KIT INCLUDES

- Pre-assembled, tested counter board
- Case, power supply, connectors, hardware
- Built-in prescaler & preamp
- Gate Light - Automatic Zero Blanking
- Automatic Decimal Point
- One to two hours assembly time
- One Year Warranty on all parts
- All new parts - not factory seconds or surplus

3550 Kit	**$99.95**
T-101 Telescopic Antenna	**3.95**
AC-9 Battery Eliminator	**7.95**
Cigarette Lighter DC Adapter	**2.95**

TERMS: Orders to U.S. and Canada, add 5% to maximum of $10.00 per order for shipping, handling and insurance. To all other countries, add 15% of total order. California Residents add 6% State Sales Tax.

NEW — NEW — NEW *from* DATA SIGNAL

TOUCH TONE® MICROPHONE

DataCoder 5

$39.00

JUST LOOK AT THESE FEATURES:

- Tough "Mobile Environment" Microphone
- Positive-Action Tactile Keys
- High-Impedance Ceramic **or** 500-ohm Dynamic Cartridge
- Adjustable Tone Balance and Output Level
- "Positive Hold - Easy Lift" Hanger
- For Vehicle or Hand-held Portable Use
- Complete . . . **Not a Kit . . . $39.00**

MINIATURE ENCODERS DTM

MODEL DTM — Completely self-contained miniature encoder for hand-held portables. Only 5/16" thick. Three wire connection. Automatic PTT keying optional. With your choice of keyboards. **Price DTM - $39.00, DTM-PTT - $49.00.**

SUB-MINIATURE ENCODERS

MODEL SME — Smallest available Touch Tone Encoder. Thin only .05" thick, keyboard mounts directly to front of hand-held portable, while sub-miniature tone module fits inside. This keyboard allows use of battery chargers. **Price $29.00,** with your choice of keyboards. **SME** (less keyboard) **$24.00**

*Touch-Tone is a registered trade name of AT&T

DATA SIGNAL, INC.

2403 COMMERCE LANE
ALBANY, GEORGIA 31707, 912-883-4703

Be sure to ask about our new keyers and CW memory for CW buffs.

"THE PROFESSIONALS"

NEW MODEL CTR-2A • 500 MHz & 1 GHz COUNTERS

NEW Period Measurement

1 us to 1 sec.

NEW Built-in Pre-Amp

10 mv @ 150 MHz

The New Model CTR-2A Series Counters are designed and built to the highest standards to fulfill the needs of commercial communications, engineering labs and serious experimentors. With an accuracy of + .00005% (oven option) the CTR-2A can handle the most critical measurements and is about half the cost of other commercial counters.

If you need a reliable counter at an affordable price, the CTR -2A is the answer.

- Built-in Pre-Amp 10 mv @ 150 MHz
- 8 Digit .3" LED Display
- High Stability TCXO Time Base
- Built-in VHF-UHF Prescaler
- Automatic Dp Placement
- TCXO Std. ± 2 ppm
- Period Measurement (Optional)
- Input Diode Protected
- 12V-DC Operation (Optional)
- Oven Controlled Crystal (Optional) ± .5 ppm
- Selectible Gate Times - .1 & 1 sec.

500 MHz Kit CTR-2A-500K	$249.95
500 MHz Assembled CTR-2A-500A	349.95
1GHz Kit CTR-2A-1000K	399.95
1GHz Assembled CTR-2A-1000A	549.95

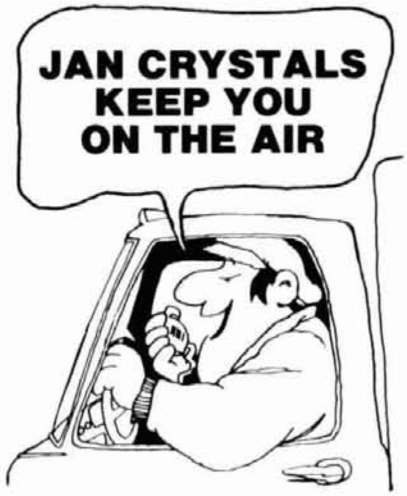
OPTIONS . . . .

02) Oven Crystal	$49.95	05) 10 sec. Time Base	$ 5.00
03) .43" LED	10.00	06) Period	15.00
04) 12 V-DC	10.00	07) Handle	10.00

PROBES
Hi-Z $15.00
•
Low Pass $15.00

DAVIS

DAVIS ELECTRONICS 636 Sheridan Dr., Tona., N.Y. 14150 716/874-5848



- CB
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- Industry
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easy to charge

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713/658-0268

KENWOOD — TR7600A

Beat the high cost of Deluxe 2 meter operation

Remote Controller (option)
• Stores • Scans
• Reads Out Frequency

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MML 144/100, 100 WATT 144 MHz LINEAR POWER AMPLIFIER

- 80 Watts Minimum Output
- Fully Protected Against Poor Load VSWR, Overheating and Excessive or Reverse Supply Rails
- Equipped with RF VOX and Manual Override
- Supplied with Power Lead and All Connectors

CALL FOR FAST QUOTES
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TERMS: All prices FOB Houston. Prices subject to change without notice. All items Guaranteed. Some items subject to prior sale. Send letterhead for Amateur dealers price list. Texas residents add 6% tax. Please add postage estimate.

W5GJ, W5MBB, K5AAD, N5JJ, W5IMJ, AG5K, WD5EDE, K5ZD, WD5ABR, WA5TGU, WD5BDX, WB5AYF, K5RC, K5BGB

Have A Nice Day!
DLA

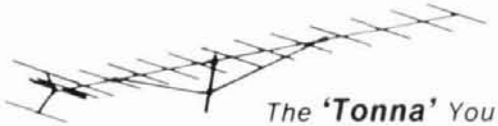
WINTER WONDERS

OMNI-J & heavy duty magnet mount complete	$49.95
TRIEX W-51 FT Self Support Tower (Reg. $825.00) Your Cost (F.O.B. California)	$725.00
Tonna F9FT Antennas 144/16el	$79.95
RIW 432/19el	$59.95
KLITZING VHF-UHF Amplifiers	
2M 10W In — 100W OUt	$198.00
432 10W In — 50 W Out	$198.00
BIRD 43 & Slugs, UPS Paid	Stock
Microwave Modules 432-28S, UPS Paid	$329.00
Telrex TB5EM, In Stock	$415.00
NEW Palomar Engr. Transceiver Preamp	$89.50
Bencher Paddles ... **$39.95;** Chrome	$49.95
ETO 76 Amplifiers	Stock
Lunar 6M-2M-220 In Line Preamps	$49.95
Lunar 2M Amp 10-80 with Preamp, UPS Paid	$189.95
Janel QSA-5	$41.95
CDE HAM-3 ... **$129.00;** HAM-X	$249.00
VHF Engrs. blue line amps	Stock
Cetron 572B	$27.95
Raytheon 572B	$24.95
Motorola HEP 170	$0.29 ea.
Mallory 2.5A/1000 PIV Epoxy Diode	$0.19 ea.
Aerovox 1000PF/500V Feed thru	$1.95
GE 6146B or 8950	$7.95
Technical books: AMECO, ARRL, Sams, TAB, Rider, Radio Pub., Callbook, Cowan, many others	Call
NEW BELDEN 9405 (2#16) (6#18) 8 wire Rotor Cable, heavy duty for long runs	$0.26/ft.
8448, Std. 8-wire Rotor	$0.16/ft.
9888, double shield RG8 Foam	$0.39/ft.
8214, RG8 Foam	$0.25/ft.
8237, RG-8	$0.21/ft.
8267, RG-213	$0.25/ft.
Amphonol Silver Plate PL259	$0.59
TIMES ½" Foam Hardline **$0.60/ft** ... Connectors	$15.00 ea.
7/8" Hardline **$1.50/ft.** ... Connectors	$25.00 ea.
BERKTEK RG-8X, 52 ohm, KW	$0.16/ft.
Consolidated HD-18 Ga. Galv. Tower, 10' Sec.	$29.95
Robot "Slow Scan" Now In Stock	Call
Alliance HD73 Rotor	$109.95
Teletower - self support - 55 ft/w breakover	$499.00

LATE SPECIAL: All FINCO Amateur Antennas — 10% off list in stock

THIS MONTH'S SPECIAL
ICOM IC280 — $395.00
DENTRON GLA1000 Amplifier — $319.00

16 ELEMENTS — F9FT — 144 MHz



The ***'Tonna'*** *You've been hearing about*

144/146 MHz	SWR 1.2:1
50 ohms	Wt. 4.4 kg.
length 6.4 m.	Horiz./Vert.

Side lobe attenuation 60 dB
Horizontal aperture 2 × 16° (−3 dB)
Vertical aperture 2 × 17° (−3 dB)

$79.95

9 Element 144-146 .... **$39.95**
4 Element 144-146 .... **$32.95**

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ELECTRONICS SUPPLY, INC.
1508-D McKINNEY • HOUSTON, TEXAS 77002
713/658-0268

More Details? CHECK—OFF Page 118

FREQUENCY COUNTER KIT

Outstanding Performance

Incredible Price $89^{95}

CT-50

SPECIFICATIONS:
Frequency range: 6 Hz to 65 mHz, 600 mHz with CT-600
Resolution: 10 Hz @ 0.1 sec gate, 1 Hz @ 1 sec gate
Readout: 8 digit, 0.4" high LED, direct readout in mHz
Accuracy: adjustable to 0.5 ppm
Stability: 2.0 ppm over 10° to 40° C, temperature compensated
Input: BNC, 1 megohm, 20 pf direct, 50 ohm with CT-600
Overload: 50VAC maximum, all modes
Sensitivity: less than 25 mv to 65 mHz, 50-150 mv to 600 mHz
Power: 110 VAC 5 Watts or 12 VDC @ 400 ma
Size: 6" x 4" x 2", high quality aluminum case, 2 lbs
ICS: 13 units, all socketed

The CT-50 is a versatile and precision frequency counter which will measure frequencies to 60 mHz and up to 600 mHz with the CT-600 option. Large Scale Integration, CMOS circuitry and solid state display technology have enabled this counter to match performance found in units selling for over three times as much. Low power consumption (typically 300-400 ma) makes the CT-50 ideal for portable battery operation. Features of the CT-50 include: large 8 digit LED display, RF shielded all metal case, easy pushbutton operation, automatic decimal point, fully socketed IC chips and input protection to 50 volts to insure against accidental burnout or overload. And, the best feature of all is the easy assembly. Clear, step by step instructions guide you to a finished unit you can rely on.

Order your today!

CT-50, 60 mHz counter kit	**$89.95**
CT-50WT, 60 mHz counter, wired and tested	**159.95**
CT-600, 600 mHz scaler option, add	**29.95**
CB-1, Color TV calibrator-stabilizer	**$14.95**
DP-1, DC probe, general purpose probe	**12.95**
HP-1, High impedance probe, non-loadir	**15.95**

CAR CLOCK

The UN-KIT, only 5 solder connections

Here's a super looking, rugged and accurate auto clock which is a snap to build and install. Clock movement is completely assembled—you only solder 3 wires and 2 switches, takes about 15 minutes! Display is bright green with automatic brightness control photocell—assures you of a highly readable display, day or night. Comes in a satin finish anodized aluminum case which can be attached 5 different ways using 2 sided tape. Choice of silver, black or gold case (specify).

DC-3 kit, 12 hour format	**$22.95**
DC-3 wired and tested	**$29.95**
110V AC adapter	**$5.95**

Under dash car clock

12/24 hour clock in a beautiful plastic case features: 6 jumbo RED LEDS, high accuracy (1 min/mo.), easy 3 wire hookup, display blanks with ignition, and super instructions. Optional dimmer automatically adjusts display to ambient light level.

DC-11 clock with mtg. bracket	**$27.95**
DM-1 dimmer adapter	**2.50**

PRESCALER

Extend the range of your counter to 600 mHz. Works with any counter. Includes 2 transistor pre-amp to give super sens., typically 20 mv at 150 mHz. Specify ÷10 or ÷100 ratio.

PS-1B, 600 mHz prescaler	**$59.95**
PS-1BK, 600 mHz prescaler kit	**49.95**

OP-AMP SPECIAL

741 mini dip	**12/$2.00**
B1-FET, mini dip, 741 type	**10/$2.00**

VIDEO TERMINAL

A completely self-contained, stand alone video terminal card. Requires only an ASCII keyboard and TV set to become a complete terminal unit. Two units available, common features are: single 5V supply, XTAL controlled sync and baud rates (to 9600), complete computer and keyboard control of cursor. Parity error control and display. Accepts and generates serial ASCII plus parallel keyboard input. The 3216 is 32 char. by 16 lines, 2 pages with memory dump feature. The 6416 is 64 char. by 16 lines, with scrolling, upper and lower case (optional) and has RS-232 and 20ma loop interfaces on board. Kits include sockets and complete documentation.

RE 3216, terminal card	**$149.95**
RE 6416, terminal card	**189.95**
Lower Case option, 6416 only	**13.95**
Power Supply Kit	**14.95**
Video/RF Modulator, VD-1	**6.95**
Assembled, tested units, add	**60.00**

CALENDAR ALARM CLOCK

The clock that's got it all. 6-.5" LEDs, 12/24 hour, snooze, 24 hour alarm, 4 year calendar, battery backup, and lots more. The super 7001 chip is used. Size: 5x4x2 inches.
Complete kit, less case (not available)

DC-9	**$34.95**

30 Watt 2 mtr PWR AMP

Simple Class C power amp features 8 times power gain. 1 W in for 8 out, 2 in for 15 out, 4 W in for 30 out. Max. output of 35 W, incredible value, complete with all parts, less case and T-R relay.

PA-1, 30 W pwr amp kit	**$22.95**
TR-1, RF sensed T-R relay kit	**6.95**

FM MINI MIKE KIT

A super high performance FM wireless mike kit! Transmits a stable signal up to 300 yards with exceptional audio quality by means of its built in electret mike. Kit includes case, mike, on-off switch, antenna, battery and super instructions. This is the finest unit available.

FM-3 kit	**$12.95**
FM-3 wired and tested	**16.95**

CLOCK KITS

our Best Seller your Best Deal

Try your hand at building the finest looking clock on the market. Its satin finish anodized aluminum case looks great anywhere, while six .4" LED digits provide a highly readable display. This is a complete kit, no extras needed, and it only takes 1-2 hours to assemble. Your choice of case colors: silver, gold, bronze, black, blue (specify).

Clock kit, 12/24 hour, DC-5	**$22.95**
Clock with 10 min. ID timer, 12/24 hour, DC-10	**27.95**
Alarm clock, 12 hour only, DC-8	**24.95**
12V DC car clock, DC-7	**27.95**

For wired and tested clocks add $10.00 to kit price.

Hard to find PARTS

LINEAR ICs		**REGULATORS**	
301	$ .35	78MG	$1.25
324	1.50	723	.50
380	1.25	309K	.85
380-8	.75	7805	.85
555	.45	78L05	.25
556	.85	7905	1.25
566	1.15	7812	.85
567	1.25	7912	1.25
1458	.50	7815	.85
3900	.50	**TTL ICs**	
CMOS ICs		74S00	.35
4011	.20	7447	.65
4013	.35	7475	.50
4046	1.85	7490	.50
4049	.40	74196TI	1.35
4518	1.25	**SPECIAL ICs**	
5369	1.75	11C90	13.50
TRANSISTORS		10116	1.25
2N3904 type	10/1.00	4511	2.00
2N3906 type	10/1.00	5314	2.95
NPN 30W Pwr	3/1.00	5375AB	2.95
PNP 30W Pwr	3/1.00	7001	6.50
2N3055	.60	4059 – N	9.00
UJT 2N2646 type	3/2.00	7208	17.95
FET MPF102 type	3/2.00	**LEDs**	
UHF 2N5179 type	3/2.00	Jumbo red	8/1.00
MRF-238 RF	11.95	Jumbo green	6/1.00
SOCKETS		Jumbo yellow	6/1.00
8 pin	10/2.00	Mini red	8/1.00
14 pin	10/2.00	Micro red	8/1.00
16 pin	10/2.00	BiPolar	.75
24 pin	4/2.00	**FERRITE BEADS**	
28 pin	4/2.00	With info., specs	15/1.00
40 pin	3/2.00	6 hole balun	5/1.00

Ramsey's famous MINI-KITS

FM WIRELESS MIKE KIT

Transmits up to 300' to any FM broadcast radio, uses any type of mike. Runs on 3 to 9V. Type FM-2 has added sensitive mike preamp stage.

FM-1 kit **$2.95** FM-2 kit **$4.95**

COLOR ORGAN/MUSIC LIGHTS

See music come alive! 3 different lights flicker with music. One light for lows, one for the mid-range and one for the highs. Each channel individually adjustable, and drives up to 300W. Great for parties, band music, nite clubs and more.

Complete kit, ML-1 **$7.95**

LED BLINKY KIT

A great attention getter which alternately flashes 2 jumbo LEDs. Use for name badges, buttons, warning panel lights, anything! Runs on 3 to 15 volts.

Complete kit, BL-1 **$2.95**

VIDEO MODULATOR KIT

Converts any TV to video monitor. Super stable, tunable over ch. 4-6. Runs on 5-15V, accepts std. video signal. Best unit on the market!

Complete kit, VD-1 **$6.95**

TONE DECODER

A complete tone decoder on a single PC board. Features: 400-5000 Hz adjustable range via 20 turn pot, voltage regulation, 567 IC. Useful for touch-tone decoding, tone burst detection, FSK, etc. Can also be used as a stable tone encoder. Runs on 5 to 12 volts.

Complete kit, TD-1 **$5.95**

WHISPER LIGHT KIT

An interesting kit, small mike picks up sounds and converts them to light. The louder the sound, the brighter the light. Completely self-contained, includes mike, runs on 110VAC, controls up to 300 watts.

Complete kit, WL-1 **$6.95**

SUPER SLEUTH

A super sensitive amplifier which will pick up a pin drop at 15 feet! Great for monitoring baby's room or as general purpose amplifier. Full 2 W rms output, runs on 6 to 15 volts, uses 8-45 ohm speaker.

Complete kit, BN-9 **$5.95**

POWER SUPPLY KIT

Complete triple regulated power supply provides variable 6 to 18 volts at 200 ma and +5V at 1 Amp. Excellent load regulation, good filtering and small size. Less transformers, requires 6.3V @ 1 A and 24 VCT.

Complete kit, PS-3LT **$6.95**

SIREN KIT

Produces upward and downward wail characteristic of a police siren. 5 W peak audio output, runs on 3-15 volts, uses 3-45 ohm speaker.

Complete kit, SM-3 **$2.95**

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BOX 4072, ROCHESTER, N.Y. 14610

PHONE ORDERS CALL (716) 271-6487

TERMS: Satisfaction guaranteed or money refunded. COD, add $1.50. Minimum order $6.00. Orders under $10.00, add $.75. Add 5% for postage, insurance, handling. Overseas, add 15%. NY residents, add 7% tax.

More Details? CHECK—OFF Page 118

TIMETRAC

By Comus

NEW!

FIRST TIME OFFER

RELAX AND LET TIMETRAC DO YOUR REMEMBERING.
TIMETRAC helps manage your busy schedule, increases your efficiency. Every home and office needs TIMETRAC.

TIMETRAC — THE CLOCK THAT REMEMBERS
This is the exciting, all new time-minder that combines space-age technology with everyday practicality. It remembers and reminds you of everything that you might forget. TimeTrac combines smart, modern design with precision and performance. Its vacuum fluorescent display provides readability from a distance (the largest display on the market today). You control the display brightness with a dimmer switch.

NOT A KIT

the microcomputer controlled appointment clock

A NEW SOLUTION FOR SOME OLD PROBLEMS
Your spouse will never be upset with you for missing a birthday.
Your business associates will be pleased when you're never late for appointments.
Your doctor will be confident that you are taking your medication at the time prescribed.

FOR THE BUSY EXECUTIVE
Controls length of business meetings. Reminds you 10 minutes ahead of time to prepare for meeting and gives you time to clear your desk. Reminder of wife's birthday. Reminder to catch plane for important business trip.

FOR THE HOMEMAKER
Reminder to take meat out of freezer for dinner. Kitchen timer. Reminder of tennis dates and hair dresser appointments.

FOR THE MOTHER
Time children's phone calls, homework, music practice. Wake children for school.

FOR THE SENIOR CITIZEN
Medication reminder. Reminder of grandchildren's birthdays, doctor appointments. Easy-to-read large display. A wonderful gift for Mom and Dad.

Regular Price $79.95
Introductory Offer By Hal-Tronix only $69.95

FOR THE STUDENT
Timer for chemistry lab, bio lab. Timer for solving problems or preparation for exams.

FOR THE GOURMET COOK
Alarms to tell you when to start next step in meal preparation. By programming the timer alarm, you'll know just when each course of an elaborate meal must be prepared so everything will be ready at the same time. Helps you keep track of recipe timing.

FOR THE SALESMAN
Stores up to 30 future appointments — easy to see at the touch of a key when next appointment is scheduled.

FOR THE PHOTOGRAPHER
Timer for photographic development chain. Can insert red digital display filter to avoid damaging film.

FOR THE ATTORNEY
Records client's time charges, meetings, phone calls, research. Timer with built-in pause capability provides accurate way of timing speech presentations.

FOR THE SECRETARY
The secretary's best friend. Remembers to remind the boss of key appointments. Times length of phone calls.

TIMETRAC FEATURES

- Sleek modern styling to complement any home or office decor.
- Tells the time.
- Tells the date and year.
- Up-timer to 60 minutes, 59 seconds with pause.
- Alarm to ring at the same time, everyday.
- Daily appointment sets appointments for the next 23 hours, 59 minutes.
- Future appointments up to one year.
- Dimmer switch for display.
- Memory will hold up to 30 appointments.
- Lithium power cell to retain memory during power outage.
- Appointments entered out of chronological order will be stored in chronological order.
- Colon flashes once each second.
- A.M./P.M. indicator.
- Plugs into any wall outlet.
- Easy to read vacuum fluorescent display.
- Extremely accurate quartz crystal clock.

THE TIMETRAC COMPUTER APPOINTMENT ALARM.
Efficient. Remarkable.
Ask your salesman for a demonstration.

THE ONLY CLOCK OF ITS KIND — NONE CAN COMPARE!

TIMETRAC SOLD AND DISTRIBUTED BY HAL-TRONIX. DEALERS WELCOME.

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HAL-TRONIX

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SEND 15¢ STAMP OR S.A.S.E. FOR INFORMATION AND FLYER ON OTHER HAL-TRONIX PRODUCTS.
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VISA AND MASTER CHARGE ACCEPTED.

Repeater Jammers Running You Ragged?

Here's a portable direction finder that REALLY works—on AM, FM, pulsed signals and random noise! Unique left-right DF allows you to take accurate (up to 2°) and fast bearings, even on short bursts. Its 3dB antenna gain and .06 μV typical DF sensitivity allow this crystal-controlled unit to hear and positively track a weak signal at very long ranges—while the built-in RF gain control with 120 dB range permits positive DF to within a few feet of the transmitter. It has no 180° ambiguity and the antenna can be rotated for horizontal polarization.

The DF is battery-powered, can be used with accessory antennas, and is 12/24V for use in vehicles or aircraft. It is available in the 140-150 MHz VHF band and/or 220-230 MHz UHF band. This DF has been successful in locating malicious interference sources, as well as hidden transmitters in "T-hunts", ELTs, and noise sources in RFI situations.

Price for the single band unit is $170, for the VHF/UHF dual band unit is $205, plus crystals. Write or call for information and free brochure.

W6GUX

L-TRONICS
5546 Cathedral Oaks Road
(Attention Ham Dept.)
Santa Barbara, CA 93111

WD6ESW

SUB-AUDIBLE GENERATOR for FM

THE CUBE

.5 x .6 x .8 in.

- Inexpensive multi tone encoder
- Compatible with PL-CG-QC
- Low distortion sinewave
- Input 8-18 VDC unregulated
- Rugged, plastic encased with leads
- Adjustable frequency (98-250 Hz), Lower available
- Excellent stability

Price $19.95

Freq. set at factory $5.00 extra

Calif. res. add 6%

Send for more info

Lyle Products

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HI-Q BALUN

- For dipoles, yagis, inverted vees, doublets & quads
- For full legal power & more
- Puts power in antenna
- Broadbanded 3-40Mhz.
- Small, light, weather-proof
- 1:1 Impedance ratio
- Replaces center insulator
- Helps eliminate TVI
- Fully Guaranteed

$9.95 PPD U.S.A.

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More Details? CHECK—OFF Page 118

State of the art by K.V.G.

CRYSTAL FILTERS and DISCRIMINATORS

9.0 MHz FILTERS

XF9-A	2.5 kHz	SSB TX	$40.65
XF9-B	2.4 kHz	SSB RX/TX	$55.10
XF9-C	3.75 kHz	AM	$59.30
XF9-D	5.0 kHz	AM	$59.30
XF9-E	12.0 kHz	NBFM	$59.30
XF9-M	0.5 kHz	CW (4 pole)	$41.50
XF9-NB	0.5 kHz	CW (8 pole)	$73.45

9.0 MHz CRYSTALS (Hc25/u)

XF900	9000.0 kHz	Carrier	$4.75
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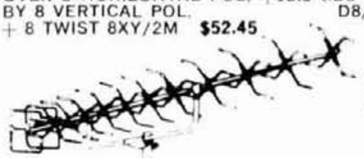

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74LS21	29	74LS93	59	74LS192	89
74LS22	29	74LS95	79	74LS193	89
74LS26	29	74LS96	89	74LS194	89
74LS27	29	74LS107	35	74LS195	89
74LS28	29	74LS109	35	74LS253	79
74LS30	23	74LS112	35	74LS257	69
74LS32	29	74LS123	99	74LS258	1.39
74LS40	29	74LS125	69	74LS260	55
74LS42	69	74LS132	79	74LS279	59
		74LS136	39	74LS367	59
				74LS368	59
				74LS670	1.95

Vigilite

Electronic Home Security Timer

A microprocessor-based pre-programmed light control that fits into a home wall socket, replacing the standard on/off light switch. Discourages intruders and burglars by turning lights on and off in a "real life" pattern while you're away.

Unlike other electromechanical timers Vigilite can simulate the lighting patterns of five different rooms as selected by the user. Vigilite can also control over-head lights, which other timers cannot. Three Vigilite units, simulating kitchen, bathroom, and bedroom lighting can give a home ultimate protection, because the user chooses a lighting pattern that depicts his real life pattern. He then sets the Vigilite clock and room pattern accordingly. (See bar chart below.) The house actually looks occupied, although no one is home.

Easy to install, the Vigilite unit contains an accurate digital LED clock, plus pre-programmed independent lighting patterns for bedroom, bathroom, kitchen, living room, and outside porch lights. All solid-state components assure the user long product life and reliability.

Technical Specifications

1) Electrical requirements—120 VAC, 60Hz, 2½ Amps
2) For use with permanently installed incandescent 40 W to 300 W light fixtures—single pole circuits
3) Cannot be used to control television, appliances, or other motor driven equipment.
4) One vigilite unit required for each room circuit.

Part Number VGL-1

$39.95 ea.

DISCRETE LEDS

.200" dia.			.125" dia.		
XC556R red	5/$1		XC209R red	5/$1	
XC556G green	4/$1		XC209G green	4/$1	
XC556Y yellow	4/$1		XC209Y yellow	4/$1	
XC556C clear	4/$1				
.200" dia.			.185" dia.		
XC22R red	5/$1		XC526R red	5/$1	
XC22G green	4/$1		XC526G green	4/$1	
XC22Y yellow	4/$1		XC526Y yellow	4/$1	
.170" dia.			XC526C clear	4/$1	
MV10B red	4/$1		.190" dia.		
.085" dia.			XC111R red	5/$1	
MV50 red	6/$1		XC111G green	4/$1	
INFRA-RED LED 1/4"x1/4"x1/16" flat	5/$1		XC111Y yellow	4/$1	
			XC111C clear	4/$1	

TIMEX T1001
LIQUID CRYSTAL DISPLAY
FIELD EFFECT

4 DIGIT — .5" CHARACTERS
THREE ENUNCIATORS
2.00" X 1.20" PACKAGE
INCLUDES CONNECTOR

T1001-Transmissive $7.95
T1001A-Reflective 8.25

TELEPHONE/KEYBOARD CHIPS

AY-5-9100	Push Button Telephone Dialler	$14.95
AY-5-9200	Repertory Dialler	14.95
AY-5-9500	CMOS Clock Generator	4.95
AY-5-2376	Keyboard Encoder (88 keys)	14.95
HD0165	Keyboard Encoder (16 keys)	7.95
74C922	Keyboard Encoder (16 keys)	9.95

ICM CHIPS

ICM7045	CMOS Precision Timer	24.95
ICM7205	CMOS LED Stopwatch/Timer	19.95
ICM7207	Oscillator Controller	7.50
ICM7208	Seven Decade Counter	19.95
ICM7209	Clock Generator	6.95

NMOS READ ONLY MEMORIES

MCM6571	128 X 9 X 7 ASCII Shifted with Greek	13.50
MCM6574	128 X 9 X 7 Math Symbol & Pictures	13.50
MCM6575	128 X 9 X 7 Alphanumeric Control Character Generator	13.50

MISCELLANEOUS

TL074CN	Quad Low Noise bi-fet Op Amp	2.49
TL494CN	Switching Regulator	4.49
TL496CP	Single Switching Regulator	1.75
11C90	Divide 10/11 Prescaler	19.95
95H90	Hi-Speed Divide 10/11 Prescaler	11.95
4N33	Photo-Darlington Opto-Isolator	3.95
MK50240	Top Octave Freq. Generator	17.50
DS0026CH	5Mhz 2-phase MOS clock driver	3.75
TIL308	.27" red num. display w/integ. logic chip	10.50
MM5320	TV Camera Sync. Generator	14.95
MM5330	4½ Digit DPM Logic Block	5.95
LD110/111	3½ Digit A/D Converter Set	25.00/set

LITRONIX ISO-LIT 1
Photo Transistor Opto-Isolator
(Same as MCT 2 or 4N25)
2/99¢

SN 76477
SOUND GENERATOR
Generates Complex Sounds
Low Power - Programmable
3.95 each

TV GAME CHIP AND CRYSTAL
AY-3-8500-1 and 2.01 MHZ Crystal (Chip & Crystal includes score display, 6 games and select angles, etc. **7.95/set**

EXAR

XR205	$3.40			XR2242CP	1.50
XR210	4.40			XR2264	4.25
XR215	4.40			XR2556	3.20
XR320	1.55	JE2206KA	14.95	XR2567	2.99
XR-L555	1.50	JE2206KB	19.95	XR3403	1.25
XR555	39	XR1800	3.20	XR4136	1.25
XR556	99	XR2206	4.40	XR4151	2.85
XR567CP	99	XR2207	3.85	XR4194	1.45
XR567CT	1.25	XR2208	5.20	XR4202	3.60
XR1310P	1.30	XR2209	1.75	XR4212	2.05
XR1468CN	3.85	XR2211	5.25	XR4558	75
XR1488	1.39	XR2212	4.35	XR4739	1.15
XR1489	1.39	XR2240	3.45	XR4741	1.47

DISPLAY LEDS

TYPE	POLARITY	HT	PRICE	TYPE	POLARITY	HT	PRICE
MAN 1	Common Anode-red	270	2.95	MAN 6730	Common Anode-red ± 1	560	99
MAN 2	5 x 7 Dot Matrix-red	300	4.95	MAN 6740	Common Cathode-red-D.D.	560	99
MAN 3	Common Cathode-red	125	25	MAN 6750	Common Cathode-red ± 1	560	99
MAN 4	Common Cathode-red	187	1.95	MAN 6760	Common Anode-red	560	99
MAN 7G	Common Anode-green	300	1.25	MAN 6780	Common Cathode-red	560	99
MAN 7Y	Common Anode-yellow	300	99	DL701	Common Anode-red ± 1	300	99
MAN 72	Common Anode-red	300	99	DL704	Common Cathode-red	300	99
MAN 74	Common Cathode-red	300	1.25	DL707	Common Anode-red	300	99
MAN 82	Common Anode-yellow	300	99	DL728	Common Cathode-red	500	1.49
MAN 84	Common Cathode-yellow	300	99	DL741	Common Anode-red	600	1.25
MAN 3620	Common Anode-orange	300	99	DL746	Common Anode-red ± 1	630	1.49
MAN 3630	Common Anode-orange ± 1	300	99	DL747	Common Anode-red	600	1.49
MAN 3640	Common Cathode-orange	300	99	DL749	Common Cathode-red ± 1	630	1.49
MAN 4610	Common Anode-orange	300	99	DL750	Common Cathode-red	600	1.49
MAN 4640	Common Cathode-orange	400	99	DL338	Common Cathode-red	110	35
MAN 4710	Common Anode-red	400	99	FND70	Common Cathode	250	69
MAN 4730	Common Anode-red ± 1	400	99	FND358	Common Cathode ± 1	357	99
MAN 4740	Common Cathode-red	400	99	FND359	Common Cathode	357	75
MAN 4810	Common Anode-yellow	400	99	FND503	Common Cathode(FND500)	500	99
MAN 4840	Common Cathode-yellow	400	99	FND507	Common Anode (FND510)	500	99
MAN 6610	Common Anode-orange-D.D.	560	99	5082-7730	Common Anode-red	300	1.30
MAN 6630	Common Anode-orange ± 1	560	99	HDSP-3400	Common Anode-red	800	2.10
MAN 6640	Common Cathode-orange-D.D.	560	99	HDSP-3403	Common Cathode red	800	2.10
MAN 6650	Common Cathode-orange ± 1	560	99	5082-7300	4 x 7 sgl. Digit-RHDP	600	19.95
MAN 6660	Common Anode-orange	560	99	5082-7302	4 x 7 Sgl. Digit-LHDP	600	19.95
MAN 6680	Common Cathode-orange	560	99	5082-7304	Overrange character (±1)	600	15.00
MAN 6710	Common Anode-red-D.D.	560	99	5082-7340	4 x 7 Sgl. Digit-Hexadecimal	600	22.50

DIODES

TYPE	VOLTS	W	PRICE	TYPE	VOLTS	W	PRICE
1N746	3.3	400m	4/1.00	1N4002	100 PIV	1 AMP	12/1.00
1N751	5.1	400m	4/1.00	1N4003	200 PIV	1 AMP	12/1.00
1N752	5.6	400m	4/1.00	1N4004	400 PIV	1 AMP	12/1.00
1N753	6.2	400m	4/1.00	1N4005	600 PIV	1 AMP	10/1.00
1N754	6.8	400m	4/1.00	1N4006	800 PIV	1 AMP	10/1.00
1N757	9.0	400m	4/1.00	1N4007	1000 PIV	1 AMP	10/1.00
1N759	12.0	400m	4/1.00	1N3600	50	200m	6/1.00
1N959	8.2	400m	4/1.00	1N4148	75	10m	15/1.00
1N965	15	400m	4/1.00	1N4154	35	10m	12/1.00
1N5232	5.6	500m	28	1N4305	75	25m	15/1.00
1N5234	6.2	500m	28	1N4734	5.6	1w	28
1N5235	6.8	500m	28	1N4735	6.2	1w	28
1N5236	7.5	500m	28	1N4736	6.8	1w	28
1N5242	12	500m	28	1N4738	8.2	1w	28
1N5245	15	500m	28	1N4742	12	1w	28
1N456	25	40m	6/1.00	1N4744	15	1w	28
1N458	150	7m	6/1.00	1N1183	50 PIV	35 AMP	1.60
1N485A	180	10m	5/1.00	1N1184	100 PIV	35 AMP	1.70
1N4001	50 PIV	1 AMP	12/1.00	1N1185	150 PIV	35 AMP	1.70
				1N1186	200 PIV	35 AMP	1.80
				1N1188	400 PIV	35 AMP	3.00

RCA LINEAR

CA3013T	2.15	CA3082N	2.00
CA3023T	2.56	CA3083N	1.60
CA3035T	2.48	CA3086N	85
CA3039T	1.35	CA3089N	3.75
CA3046N	1.30	CA3130T	1.39
CA3059N	3.25	CA3140T	1.25
CA3060N	3.25	CA3160T	1.25
CA3080T	85	CA3401N	49
CA3081N	2.00	CA3600N	3.50

CALCULATOR CHIPS/DRIVERS

MM5725	$2.95
MM5738	2.95
DM8864	2.00
DM8865	1.00
DM8887	75
DM8889	75
9374 7 seg C.A. LED driver	1.50

CLOCK CHIPS

MM5309	$4.95
MM5311	4.95
MM5312	4.95
MM5314	4.95
MM5316	6.95
MM5318	9.95
MM5369	2.95
MM5387/1998A	4.95
MM5841	9.95

MOTOROLA

MC1408L7	$4.95
MC1408L8	5.75
MC1439L	2.95
MC3022P	2.95
MC3061P	3.50
MC4016(74416)	7.50
MC4024P	3.95
MC4040P	6.95
MC4044P	4.50

SCR AND FW BRIDGE RECTIFIERS

C36D	15A @ 400V	SCR(2N1849)	$1.95
C38M	35A @ 600V	SCR	1.95
2N2328	1.6A @ 300V	SCR	50
MDA 980-1	12A @ 50V	FW BRIDGE REC	1.95
MDA 980-3	12A @ 200V	FW BRIDGE REC	1.95

TRANSISTORS

C106B1	50			2N3904	4/1.00
MPSA05	30	2N3055	89	2N3905	4/1.00
MPSA06	5/1.00	MJE3055	1.00	2N3906	4/1.00
TIS97	6/1.00	2N3392	5/1.00	2N4013	3/1.00
TIS98	6/1.00	2N3398	5/1.00	2N4123	6/1.00
40409	1.75	PN3567	3/1.00	PN4249	4/1.00
40410	1.75	PN3568	4/1.00	PN4250	4/1.00
40673	1.75	PN3569	4/1.00	2N4400	4/1.00
2N918	4/1.00	MPS3638A	5/1.00	2N4401	4/1.00
2N2219A	2/1.00	MPS3702	5/1.00	2N4402	4/1.00
2N2221A	4/1.00	2N3704	5/1.00	2N4403	4/1.00
2N2222A	5/1.00	MPS3704	5/1.00	2N4409	5/1.00
PN2222 Plastic	7/1.00	2N3705	5/1.00	2N5086	4/1.00
2N2369	5/1.00	MPS3705	5/1.00	2N5087	4/1.00
2N2369A	4/1.00	2N3706	5/1.00	2N5088	4/1.00
MPS2369	5/1.00	MPS3706	5/1.00	2N5089	4/1.00
2N2484	4/1.00	2N3707	5/1.00	2N5129	5/1.00
2N2906	4/1.00	2N3711	5/1.00	PN5134	5/1.00
2N2907	5/1.00	2N3724A	65	PN5138	5/1.00
PN2907 Plastic	7/1.00	2N3725A	1.00	2N5139	5/1.00
2N2925	5/1.00	2N3772	2.25	2N5210	5/1.00
MJE2955	1.25	2N3823	1.00	2N5449	3/1.00
2N3053	2/1.00	2N3903	5/1.00	2N5951	3/1.00

IC SOLDERTAIL — LOW PROFILE (TIN) SOCKETS

	1-24	25-49	50-100		1-24	25-49	50-100
8 pin LP	$.17	16	15	22 pin LP	$.37	36	35
14 pin LP	20	19	18	24 pin LP	38	37	36
16 pin LP	22	21	20	28 pin LP	45	44	43
18 pin LP	29	28	27	36 pin LP	60	59	58
20 pin LP	34	32	30	40 pin LP	63	62	61

SOLDERTAIL STANDARD (TIN)

	1-24	25-49	50-100		1-24	25-49	50-100
14 pin ST	$.27	25	24	28 pin ST	$.99	90	81
16 pin ST	30	27	25	36 pin ST	1.39	1.26	1.15
18 pin ST	35	32	30	40 pin ST	1.59	1.45	1.30
24 pin ST	49	45	42				

SOLDERTAIL STANDARD (GOLD)

	1-24	25-49	50-100		1-24	25-49	50-100
8 pin SG	$.30	27	24	24 pin SG	$.70	63	57
14 pin SG	35	32	29	28 pin SG	1.10	1.00	90
16 pin SG	38	35	32	36 pin SG	1.65	1.40	1.26
18 pin SG	52	47	43	40 pin SG	1.75	1.59	1.45

WIRE WRAP SOCKETS (GOLD) LEVEL #3

	1-24	25-49	50-100		1-24	25-49	50-100
8 pin WW	$.39	35	31	22 pin WW	$.95	85	75
10 pin WW	45	41	37	24 pin WW	1.05	95	85
14 pin WW	39	38	37	28 pin WW	1.40	1.25	1.10
16 pin WW	43	42	41	36 pin WW	1.59	1.45	1.30
18 pin WW	75	68	62	40 pin WW	1.75	1.55	1.40

1/4 WATT RESISTOR ASSORTMENTS – 5%

ASST. 1	5 ea	10 OHM, 12 OHM, 15 OHM, 18 OHM, 22 OHM, 27 OHM, 33 OHM, 39 OHM, 47 OHM, 56 OHM	50 PCS	$1.75
ASST. 2	5 ea	68 OHM, 82 OHM, 100 OHM, 120 OHM, 150 OHM, 180 OHM, 220 OHM, 270 OHM, 330 OHM, 390 OHM	50 PCS	1.75
ASST. 3	5 ea	470 OHM, 560 OHM, 680 OHM, 820 OHM, 1K, 1.2K, 1.5K, 1.8K, 2.2K, 2.7K	50 PCS	1.75
ASST. 4	5 ea	3.3K, 3.9K, 4.7K, 5.6K, 6.8K, 8.2K, 10K, 12K, 15K, 18K	50 PCS	1.75
ASST. 5	5 ea	22K, 27K, 33K, 39K, 47K, 56K, 68K, 82K, 100K, 120K	50 PCS	1.75
ASST. 6	5 ea	150K, 180K, 220K, 270K, 330K, 390K, 470K, 560K, 680K, 820K	50 PCS	1.75
ASST. 7	5 ea	1M, 1.2M, 1.5M, 1.8M, 2.2M, 2.7M, 3.3M, 3.9M, 4.7M, 5.6M	50 PCS	1.75

ASST. 8R Includes Resistor Assortments 1-7 (350 PCS.) **$9.95 ea.**

CAPACITOR CORNER

50 VOLT CERAMIC DISC CAPACITORS

	1-9	10-99	100-		1-9	10-99	100-
10 pf	.05	.04	.03	.001µf	.05	.04	.035
22 pf	.05	.04	.03	.0047µf	.05	.04	.035
47 pf	.05	.04	.03	.01µf	.05	.04	.035
100 pf	.05	.04	.03	.022µf	.06	.05	.04
220 pf	.05	.04	.03	.047µf	.06	.05	.04
470 pf	.05	.04	.035	.1µf	.12	.09	.075

100 VOLT MYLAR FILM CAPACITORS

.001mf	.12	.10	.07	.022mf	.13	.11	.08
.0022	.12	.10	.07	.047mf	.21	.17	.13
.0047mf	.12	.10	.07	.1mf	.27	.23	.17
.01mf	.12	.10	.07	.22mf	.33	.27	.22

+20% DIPPED TANTALUMS (SOLID) CAPACITORS

.1/35V	.28	.23	.17	1.5/35V	.30	.26	.21
.15/35V	.28	.23	.17	2.2/25V	.31	.27	.22
.22/35V	.28	.23	.17	3.3/25V	.31	.27	.22
.33/35V	.28	.23	.17	4.7/25V	.32	.28	.23
.47/35V	.28	.23	.17	6.8/25V	.36	.31	.25
.68/35V	.28	.23	.17	10/25V	.40	.35	.29
1.0/35V	.28	.23	.17	15/25V	.63	.50	.40

MINIATURE ALUMINUM ELECTROLYTIC CAPACITORS

Axial Lead				Radial Lead			
.47/50V	.15	.13	.10	.47/25V	.15	.13	.10
1.0/50V	.16	.14	.11	.47/50V	.16	.14	.11
3.3/50V	.14	.12	.09	1.0/16V	.15	.13	.10
4.7/25V	.15	.13	.10	1.0/25V	.16	.14	.11
10/25V	.15	.13	.10	1.0/50V	.16	.14	.11
10/50V	.16	.14	.12	4.7/16V	.15	.13	.10
22/25V	.17	.15	.12	4.7/25V	.15	.13	.10
22/50V	.24	.20	.18	4.7/50V	.16	.14	.11
47/25V	.19	.17	.15	10/16V	.14	.12	.09
47/50V	.25	.21	.19	10/25V	.15	.13	.10
100/25V	.24	.20	.18	10/50V	.16	.14	.12
100/50V	.35	.30	.28	47/50V	.24	.21	.19
220/25V	.32	.28	.25	100/16V	.19	.15	.14
220/50V	.45	.41	.38	100/25V	.24	.20	.18
470/25V	.33	.29	.27	100/50V	.35	.30	.28
1000/16V	.55	.50	.45	220/16V	.23	.17	.16
2200/16V	.70	.62	.55	470/25V	.31	.28	.26

$5.00 Minimum Order – U.S. Funds Only
California Residents – Add 6% Sales Tax

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

NEW 1979 Catalog

Jameco ELECTRONICS

PHONE ORDERS WELCOME (415) 592-8097

MAIL ORDER ELECTRONICS – WORLDWIDE
1021 HOWARD AVENUE, SAN CARLOS, CA 94070
Advertised Prices Good Thru January

More Details? CHECK — OFF Page 118

Coming Events

RADIO EXPO '79 September 15th and 16th, 1979, Lake County Fair Grounds, Routes 120 and 45, Grays Lake, Illinois. Manufacturers' displays, flea market, seminars, ladies programs. Advance tickets $2.00. Write EXPO, P.O. Box 305, Maywood, IL 60153. Exhibitors inquiries: EXPO Hotline (312) 345-2525.

SOUTH BEND, INDIANA Hamfest Swap & Shop, January 7, 1979, first Sunday after New Years Day at New Century Center downtown by river on U.S. 31 Oneway North *across from St. Joseph Bank Building. Half acre in one* large room at ground level. Tables $3 each. Food service, automobile museum and Art Center in same building. Four lane highways to door from all directions. Talk-in Freq: 146.52-52, 13-73, 34-94; 147.99-39, 93-33, 84-24, 69-09.

ROCHESTER Hamfest & NY State ARRL Convention, May 25-27. Add your name to mailing list. Send QSL to Rochester Hamfest, Box 1388, Rochester, NY 14603. Phone (716) 424-1100.

WASHINGTON: Pacific Northwest Hamfest, July 14 & 15, HAM Inc., Box 78442, Seattle, WA 98178.

RICHMOND, VIRGINIA FROSTFEST-II, January 14, 1978, Bon Air Community Center. Sponsored by the Richmond Amateur Telecommunications Society. Talk-in 28-88, 34-94, 52 simplex. Technical symposium, drawing, home brewers contest - 2 divisions, over 18 and under. Framed certificate to winner with the most Original Idea, Best Mechanical and Best Electrical Construction. FCC exams will be administered starting at 10:00 AM. To take exam, *mail Form 610 at least five days prior to Fest to address below.* Commercial exhibitors by invitation only write for details. Indoor Flea Market with one table $2.50, Outdoor Frost Bite tail gate $1.00. Admission $2.50, children under 2 free. Richmond Amateur Telecommunications Society, P.O. Box 1070, Richmond, VA 23208.

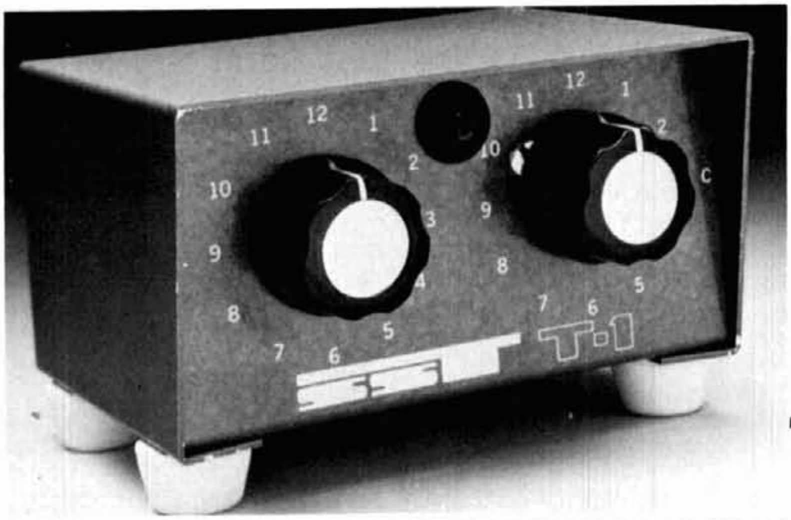
WISCONSIN: The 7th Annual Midwinter Swapfest will be held on Saturday, January 20, starting at 8:00 AM, at the Waukesha County Expo Center, Waukesha. Food, beer and prizes. Directions: I-94 to Waukesha Co. F, south to FT, west to Expo. Admission: $1.50 advanced, $2.50 at the door. Reserved tables $3.00 (until January 12). SASE Please. Write: WARAC, P.O. Box 1072, Milwaukee, Wisconsin 53201.

MICHIGAN: Southfield High School Amateur Radio Club 14th annual Swap & Shop, Sunday, January 21, 1979, Southfield High School, Southfield, Michigan at 10 Mile & Lasher. Admission $2.00. For information SASE to Mr. Robert Younkers, 24675 Lasher Road, Southfield, Michigan 48034 or call (313) 354-8210.

THE 1979 ANNUAL CONFERENCE of the New Zealand Association of Radio Transmitters, (Inc.) will be held at Upper Hutt, New Zealand, between June 1st and 4th 1979. This is the major social and chin-wag event in the New Zealand Radio Amateur's calendar. Overseas visitors to New Zealand are welcome to attend this conference. *Registration forms are available from the* Secretary, 1979 Conference Committee, P.O. Box 40-212, Upper Hutt, New Zealand.

FLORIDA: Dade Radio Club's 19th Annual Tropical Hamboree and ARRL South Florida Convention, January 27 and 28, Miami. Flagler Dog Track Auditorium. Exhibits, flea market, technical/group sessions. Free parking/overnight space for RVs on grounds. Pre-registration $3, Door $4. For information/reservations: DRC Hamboree, P.O. Box 350045, Riverside, Maimi, FL 33135 or Evelyn Gauzens, W4WYR, Hamboree Chairman, 2780 NW Third St., Miami, FL 33125. (305) 642-4139.

SST T-1 RANDOM WIRE ANTENNA TUNER



All band operation (160-10 meters) with any random length of wire. 200 watt output power capability—will work with virtually any transceiver. Ideal for portable or home operation. Great for apartments and hotel rooms—simply run a wire inside, out a window, or anyplace available. Efficient toroid inductor for small size: 4-1/4" x 2-3/8" x 3", and negligible loss. Built-in neon tune-up indicator. SO-239 connector. Attractive bronze finished enclosure.

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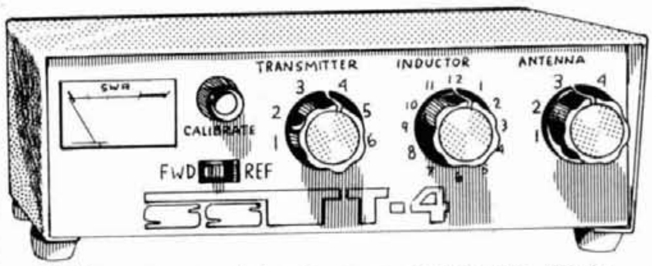

Matches any coax fed antenna or random wire. Works with any transceiver. Great for mobile, portable, or home operation. Antenna switch selects between two coax fed antennas, random wire, or tuner bypass. Attractive bronze finished enclosure with exclusive SST Styling. Compact size: 9" x 2-1/2" x 5".

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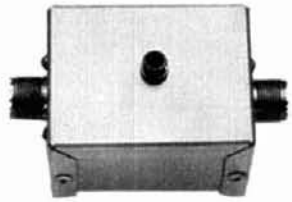

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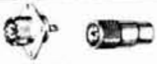

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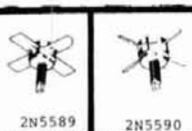

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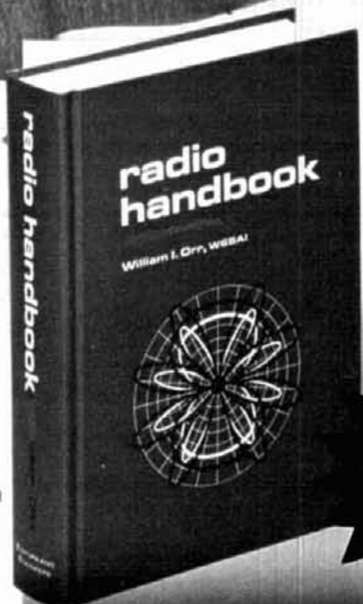

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January, 1979

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FT-225RD 2 METER TRANSCEIVER DIGITAL READOUT

ALL MODE: SSB, CW, AM, FM
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A compact versatile transceiver for the dedicated two-meter DXer, the optional memory and twenty-five watt output puts the FT-225RD far ahead. See it at your dealer's today, or write for our full line catalog.

SPECIFICATIONS:

General

Frequency Range: 144-145 MHz, 145-146 MHz, 146-147 MHz, 147-148 MHz

Frequency Readout: Digital readout to 100 Hz, analog display resolution better than 1 KHz.

Modes of Operation: LSB, USB, CW, AM, FM

Frequency Stability: Within 100 Hz during any 30 minute period after warmup. Not more than 20 Hz with 10% line voltage variation.

Intermediate Frequencies: 1st IF=10.7 MHz; 2nd IF=455 KHz.

Antenna Impedance: 50 ohms unbalanced

Repeater Split: 600 KHz installed, any split up to 1 MHz with optional crystal.

Power Requirements: AC 100/110/117/200/234 Volts
DC 13.8 Volts, negative ground

Power Consumption: AC Receive 30 VA
Transmit 160 VA at full output
DC Receive 1.2 Amps Transmit 6.5 Amps

Size: 280mm (W) × 125mm (H) × 315mm (D)

Weight: Approximately 9 kg

Receiver

Sensitivity: SSB/CW 0.3 uV for 10dB S/N
FM 0.35 uV for 20dB QS
AM 1.0 uV for 10dB S/N

Selectivity: SSB/CW/AM 2.3 KHz at 6dB down
4.1 KHz at 60dB down
FM 12 KHz at 6dB down 28 KHz at 60dB down

Image Response: Better than —60dB

Spurious Response: Better than 1 uV at antenna

Price And Specifications Subject To Change Without Notice Or Obligation

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The radio.

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