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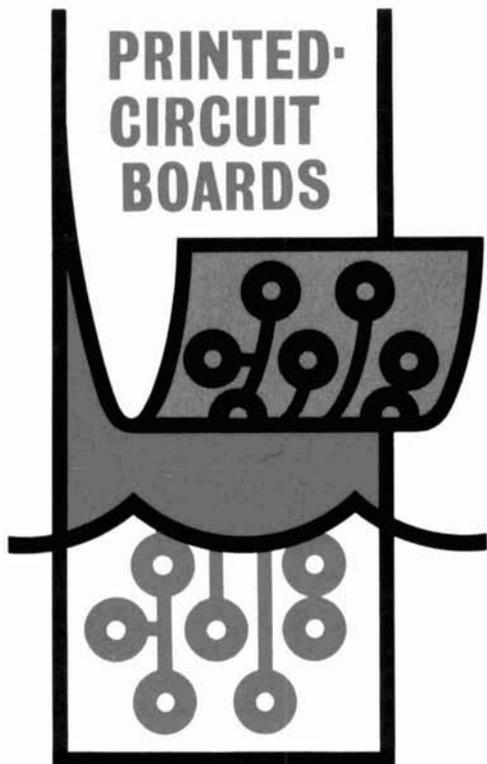
ham **radio**

magazine

SEPTEMBER 1971

PRACTICAL PHOTOFABRICATION OF

PRINTED- CIRCUIT BOARDS



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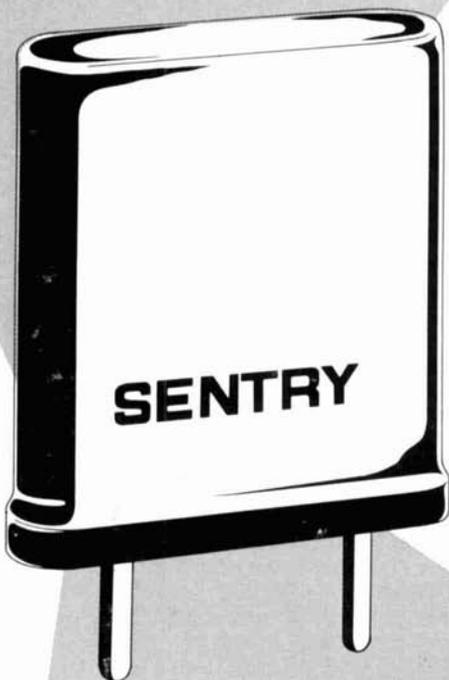
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a second look

by Jim
fisk

A new electronically-tunable ceramic capacitor has been developed by engineers at Fort Monmouth, New Jersey. The new tunable capacitor is about one-tenth the size of presently available units, equivalent to three quarters stacked on top of one another.

The tunable capacitor, which will be used in automatic tuners in lightweight military radios, costs about thirty cents. The device consists of a multilayered ferro-electric material with an rf electrode on each end and a dc electrode in the center. As the dc control voltage is varied, the dielectric constant of the center layer changes, thereby changing the capacitance of the device.

The voltage-tunable characteristic of these new ceramic capacitors is particularly valuable for applications which require automatic tuning capability. For example, the capacitor can be combined with a digital logic network to retune an antenna automatically if a mismatch occurs between it and the transmitter. In a typical application the radio can completely retune itself automatically within several microseconds.

Varactors are not suitable for this application because of their power limitations. To obtain high power, a larger number of series-connected diodes must be used; this lowers capacitance. To increase capacitance, more diodes must be placed in parallel; this results in a very unwieldy package. With the ceramic mul-

tilayer capacitor, however, a whole stack of devices can be placed in a very small package.

Since these multilayer capacitors are still in the developmental stage, it will be some time before they become available for use in radio production. Eventually they will reach the public. When they do we should see a whole new array of automatically tuned communications antennas.

For example, by including one of these tunable ceramic capacitors inside the traps of a multiband beam, an enterprising amateur could build a high-performance antenna system which would provide unity swr at any operating frequency. The required digital logic control circuitry could be built into the antenna boom.

These ceramic capacitors could also be used in automatic tuning units at the output of your transceiver, or as tuning and loading controls within the equipment. The capacitors would also be ideal for automatically tuned mobile antennas which compensate for swr changes as you drive under trees or next to large tractor-trailors. This is especially important when using solid-state final amplifier stages which quickly destroy themselves when confronted with high standing-wave ratios.

Jim Fisk, W1DTY
editor

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SPECIFICATIONS • **Frequency Range:** 10 kHz to 30.0 MHz. • **Modes of Operation:** USB, LSB, CW, RTTY, AM, ISB. • **Frequency Readout:** Complete to 100 Hz on six NIXIE tubes. • **Frequency Selection:** 10 MHz, 1 MHz, 0.1 MHz switch selected; 0 to 0.1 MHz continuously variable. • **Frequency Stability:** Drift does not exceed 150 Hz in any 15 minute period with a temperature change of 7° C per hour over a range of 0° to 40° C. • **Sensitivity:** Less than 0.5 microvolt for 10 dB SINAD at 2.4 kHz SSB mode; Less than 1.0 microvolt for 10 dB SINAD at 6 kHz AM mode. • **Image Rejection:** Greater than 70 dB relative to 1 microvolt. • **Blocking:** Greater than 100 dB relative to 1 microvolt. • **Cross Modulation:** Greater than 80 dB relative to 1 microvolt. • **Intermodulation:** Greater than 80 dB relative to 1 microvolt. • **Opposite Sideband Suppression:** Greater than 60 db at 500 Hz into the opposite sideband. • **I.F. Bandwidth:** 6 kHz, 2.4 kHz, 1.2 kHz, 0.4 kHz; Selectivity @ -6 dB: 6 kHz, 2.4 kHz, 1.2 kHz, 0.4 kHz; @ -60 dB: 11.5 kHz, 4.3 kHz, 2.4 kHz, 0.8 kHz; Optional filters available for other bandwidths. • **I.F. Outputs:** 50 millivolts into 50 ohms at 1st I.F.; 5.05 MHz and 2nd I.F. 50 kHz. • **Automatic Gain Control:** Audio Output rises less than 3 dB for RF input change of 1 microvolt to 100 millivolts; Attack time 100 microseconds; Release time 750 milliseconds (Slow AGC), 25 milliseconds (Fast AGC). • **Antenna Input Impedance:** 10 kHz to 500 kHz, 1000 ohms; 500 kHz to 30 MHz, 50 ohms. • **Audio Output:** 3 watts at 5% maximum distortion into 3.2 ohm load; 1 volt into 600 ohm output line; 3.2 ohm unbalanced and two 600 ohm balanced outputs; ISB output is one of the two 600 ohm balanced outputs. • **Audio Hum and Noise:** Greater than 60 dB below rated output. • **BFO:** Derived from standard clock or variable over a ± 3 kHz range from front panel. • **Power Requirements:** 115/230 volts ± 10% single phase 50-420 Hz 15 watts; 12 or 24 VDC supply optional. • **Dimensions:** 5.25 in. H x 19 in. W x 15 in. D, (13.3 cm H x 48 cm W x 38 cm D). • **Weight:** 17 lbs (7.7 kg).

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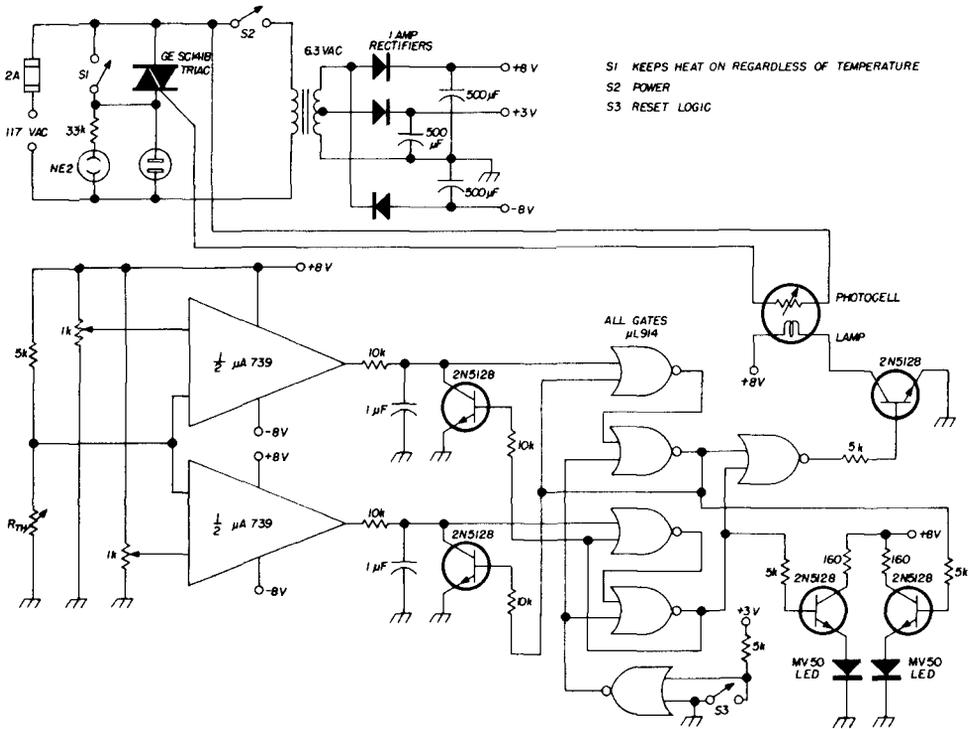
Making the printed-circuit board for a project is often as much fun as using the finished project itself. The photoresist technique is easy, inexpensive and results in a neat, professional looking and aesthetically pleasing final project. A quick scan of the literature reveals that this technique has actually been used very rarely by amateurs. This is because of the apparent unavailability of photoresist, misconceptions about cost and, of course, the absence of a comprehensive article on the subject.

The method of making printed-circuit boards detailed in this article consists of making a transparency using readily available drafting aids and coating a piece of

Completed project using the printed-circuit board.



Larry Hutchinson, Chemistry Department, Oregon State University, Corvallis, Oregon 97331



S1 KEEPS HEAT ON REGARDLESS OF TEMPERATURE
 S2 POWER
 S3 RESET LOGIC

fig. 1. Schematic of the automatic-shut-down circuit used to illustrate the photoresist method of making printed-circuit boards.*

copper-clad board with a positive-working photoresist, exposing, developing and etching. A conservative estimate of the photoresist cost for a 5 x 7-inch board is \$10. No darkroom, camera or photographic skill is required since the only

light-sensitive part of the process is the photoresist, and it is sensitive only to ultraviolet light. A photoresist-coated circuit board may be exposed to normal room lighting for an hour or longer with no harm.

*This equipment is used in an organic chemistry laboratory to automatically stop a distillation when the temperature of the material being distilled either rises above the boiling point of the pure material (indicating the presence of a higher boiling impurity) or falls below the boiling point (when most of the material is gone from the pot and not enough hot vapor is flowing past the thermistor in the distillation head to keep it hot). The Triac in the circuit is used as an on-off switch to determine whether heat is applied to the pot (through a heat controller plugged into the socket). The Triac is controlled by the logic through a lamp/photocell combination. The light-emitting diodes are used to indicate whether the distillation was shut-down due to a rise or a fall in temperature.

Techniques for making printed-circuit boards may be divided into two basic categories. Those methods characterized by application of resist to areas where copper remains after etching, and methods using photoresist or silkscreen.

The first method is useful for one-of-a-kind projects. Examples include paint, ink, tape and dry-transfer images applied directly to the circuit board. Also included is stick-on copper foil with heat-resistant adhesive; this is a very interesting material since etching and drilling are eliminated, and the circuit can be changed with relative ease.

Photoresist methods are divided into

three types: those that use a positive-working photoresist with a positive transparency, develop and etch; those that use a negative-working photoresist with a

positive photoresist is Shipley's AZ-111 which is developed in a weak solution of sodium hydroxide (lye).

Negative-working photoresists consist

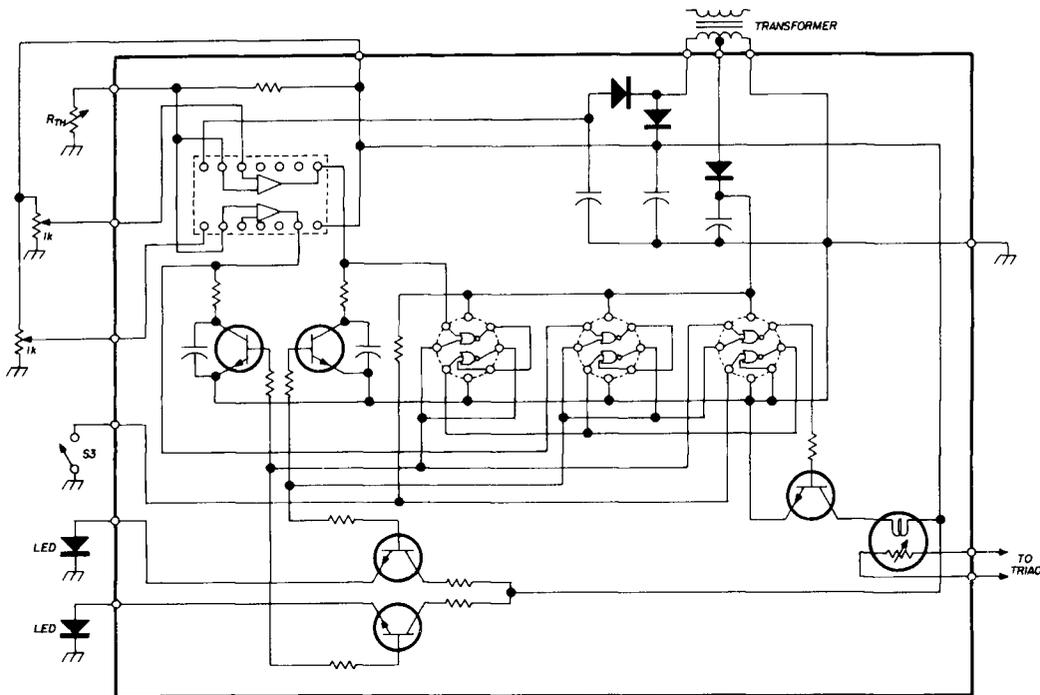


fig. 2. First step toward a printed-circuit board consists of redrawing the circuit, placing components within the proposed board outline. No attempt is made to minimize wiring crossovers at this point.

positive transparency, develop, tin plate, strip resist and etch with an etchant which will not dissolve tin; and those that use a negative-working photoresist with a negative mask, develop and etch. Although only the first method is recommended all three will be covered.

photoresists

A positive-working photoresist consists of an organic resin which is affected by ultraviolet light in such a way that the exposed resin is easily dissolved in its developer, but the unexposed material is not. Positive-working resists are resistant to pinholing and other effects caused by dust particles and other contaminants on the transparency. An example of a posi-

of an organic resin which polymerizes when exposed to ultraviolet light such that the resin becomes insoluble in a solvent in which the unexposed resin is easily dissolved. An example of a negative-working photoresist is Eastman Kodak KPR-2; this is developed in trichloroethylene, a common dry-cleaning solvent.

technique

To illustrate the techniques involved in producing a printed-circuit board from scratch I have photographed the various stages in the evolution of a recent project. Fig. 1 shows the schematic of the circuit; note that the ground and power supply leads are not fully drawn in and that the

gates and op amps are represented by symbols which have minimal resemblance to the actual ICs.

The first step is to redraw the sche-

matter to determine the maximum size and shape of the board, shown as the rectangle in **fig. 4**.

If you have the option, choose a board which is just large enough to allow horizontal mounting of resistors and capacitors. If you have not done enough bread-boarding of your project and are uncertain as to the workability of the design leave a little extra room for circuit modifications and additions.

The locations of major components such as capacitors, IC sockets and transformers are now determined. Keep in mind the positions of the external components. Pencil in an outline of the large items.

Step 3 involves redrawing the schematic, replacing all symbols with full-size outlines of the components (see **figs. 5** and **6**). This must be done accurately; the use of graph paper with 0.1-inch grids is helpful in maintaining accuracy. The actual components should be on hand during this step so you can determine if all the parts will fit correctly.

Use pencil. Unless you are working on a particularly simple circuit board you will probably do a lot of erasing. A set of colored pencils is a big help here. The finished drawing (see **fig. 6**) should be accurate with regard to component positions and all drill holes. When you are certain everything is correctly placed go over the appropriate pencil marks with a

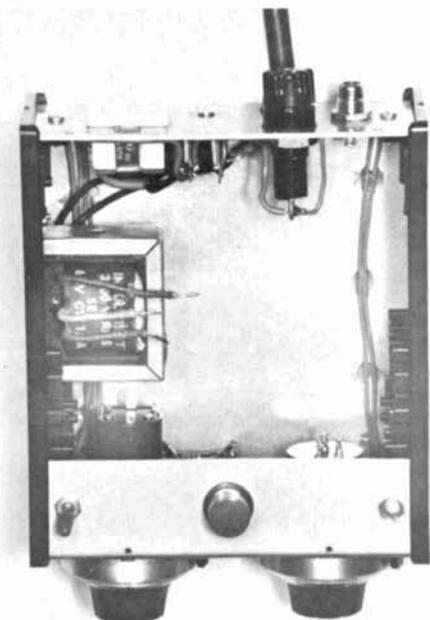


fig. 3. The size of the printed-circuit board and the number of components that it will carry are determined by selecting the enclosure for the project and wiring in those components that will not be on the circuit board.

matic according to the following rules:

1. Draw a rectangle to represent the pc board. Parts which will be external to the board should be drawn outside the rectangle in the correct relative positions.
2. Completely draw in power supply and ground leads. Do not bother to minimize lead crossing at this point.
3. Redraw the integrated circuits as shown in **fig. 2**.

For **Step 2** you need to know the size and shape of the printed-circuit board. To do this I first install and wire all the components not on the printed circuit board (see **fig. 3**). Then it is an easy

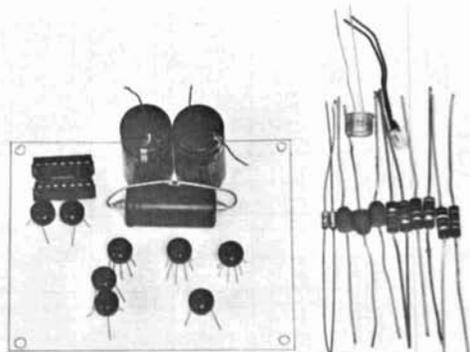


fig. 4. Circuit-board layout is further defined by placing the actual components on a graph-paper outline of the proposed board.

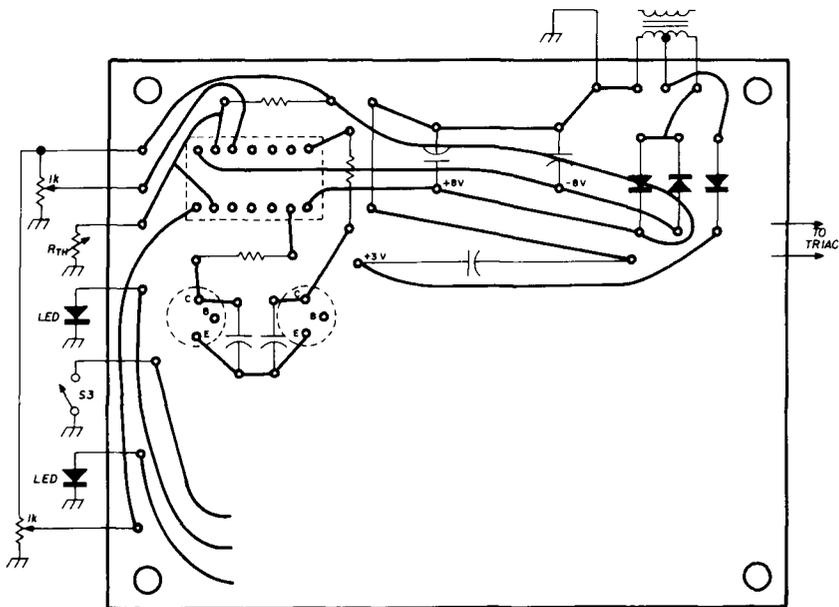


fig. 5. After choosing an initial layout begin sketching in the interconnecting wires. Avoid wiring crossovers.

red felt tip marker so the proposed foil pattern will show through in the next step (see fig. 7).

Since fig. 7 was drawn as a top view the paper must be turned over before making the transparency. A thin sheet of acetate or mylar plastic is cut a little

larger than the board and attached to the back of the diagram with masking tape (fig. 8).

the transparency

At this point you will need some of the electronic drafting aids listed in table

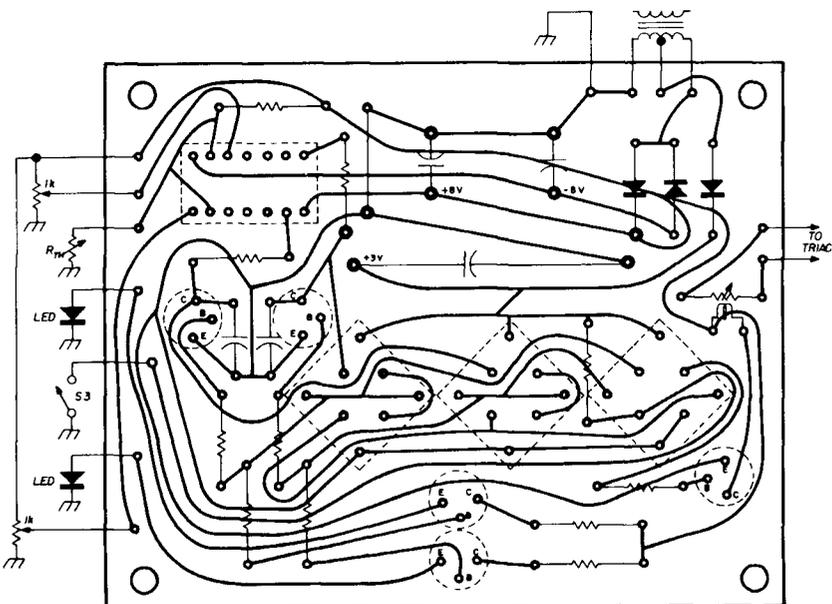


fig. 6. Continue sketching the rest of the circuit layout. Use a pencil — you will probably have to do a lot of component re-arranging to eliminate crossovers.

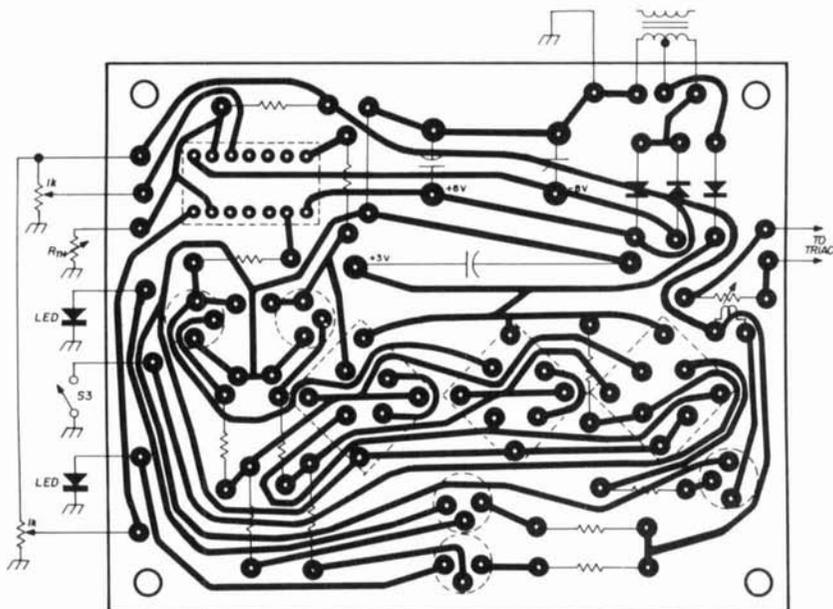


fig. 7. When you are satisfied with the layout go over each of the circuit traces with a dark marking pen.

1. A few of these drafting aids are shown in the photograph. Bishop drafting aids are available in large quantities from Bishop Graphics, and in small quantities from GC Electronics. It is most economical to purchase the most often used drafting aids (tape and donut-shaped pads) from Bishop Graphics, Trans-pak

(Chartpak) or Datak, and the less often used aids from GC Electronics. The dry-transfer drafting aids available from Datak are easier to use than conventional die-cut patterns and should not be overlooked.

The drafting aids are transferred to the plastic sheet with a small X-acto knife.

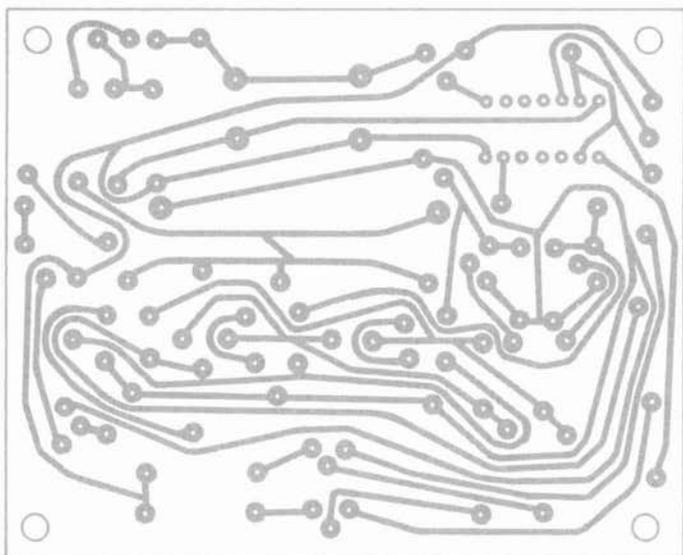


fig. 8. Flop the drawing over; the marking pen outline of the traces will show through the paper.

The donut-shaped pads and similar images should be applied first (fig. 9) followed by the tape (fig. 10). The tape is cut by pressing gently down on the knife, then pulling the free end of the tape up and to the side. It takes a little practice to cut only the tape and not what is below. When you finish the transparency inspect it carefully to see that it corresponds correctly to the circuit. If you are using a negative photoresist a contact exposure with sheet film will produce a negative transparency.

photoresist application

Cut the board to size and sand down any rough edges. The surface of the board should be scrubbed with scouring powder until all oil and fingerprints have been removed. The surface is then washed with a 5-10% solution of sulfuric or hydrochloric acid, rinsed thoroughly with running water, and dried with a paper towel.

The clean board should be coated with a thin, even layer of photoresist within an

Drafting aids used in preparing the artwork for the printed-circuit board.



table 1. Drafting aids useful in laying out printed-circuit boards. Data is arranged by catalog number, number of images or feet of tape and price.

item	Bishop	Chartpak	Datak	GC Electronic
8 lead	6026	TPCL 11-4	JD-71	21-103
TO-5	250	250	1152	20
(TO-99)	\$6.85	\$7.55	\$6.50	\$1.00
14 lead	6014	TPCL-12-1	JD-68	21-120
DIP	250	100	432	16
(TO-116)	\$7.55	\$9.70	\$6.50	\$1.00
.125" round pad	D207 500 \$3.00	TPCC-72 \$1.00	JD-124 4464 \$6.50	21-023 125 \$1.00
.187" round pad	D138 500 \$2.00	TPCC-72 \$1.00	JD-125 3120 \$6.50	21-025 126 \$1.00
.250" round pad	D109 500 \$2.00	TPCC-77 \$1.00	JD-127 1920 \$6.50	21-025 126 \$1.00
.020" tape	T201 (.020") 720 \$0.75	TP-1502 648 \$0.70	—	21-002 360 \$0.59
.040" tape	T201 (.040") 720 \$0.75	TP-0401 648 \$0.70	—	21-004 360 \$0.59
.080" tape	T201 (.080") 720 \$0.75	TP-0801 648 \$0.70	—	21-006 360 \$0.59

Bishop Graphics, Inc., 7300 Radford Avenue, North Hollywood, California 91605

Chartpak Rotex, One River Road, Leeds, Massachusetts 01053

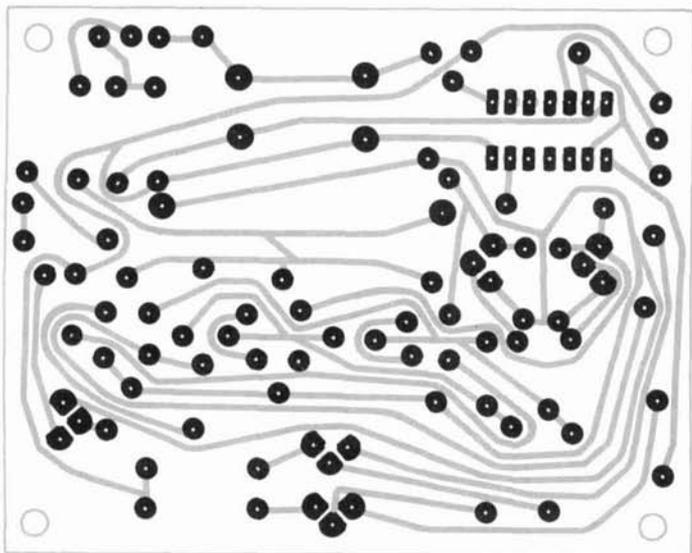
Datak Corporation, 85 Highland Avenue, Passaic, New Jersey 07055

GC Electronics, 400 South Wyman Street, Rockford, Illinois 61101

hour of cleaning. There are many ways this is done commercially including roller coating, spray coating and controlled withdrawal. However, for the amateur, spin application is the best.

Spin application consists simply of applying a generous amount of photoresist to the board and spreading it over the copper surface with a medicine dropper (fig. 11) then spinning the board at 500 to 2000 rpm for a few seconds.

fig. 9. Place the round circuit pads, IC sockets and transistor layouts in the correct positions on the plastic sheet covering the reversed circuit drawing.



The board can be spun with an electric drill or small shaded pole motor mounted vertically on a small stand. The board is attached with a suction cup; a cardboard box should be used to catch the spin-off.

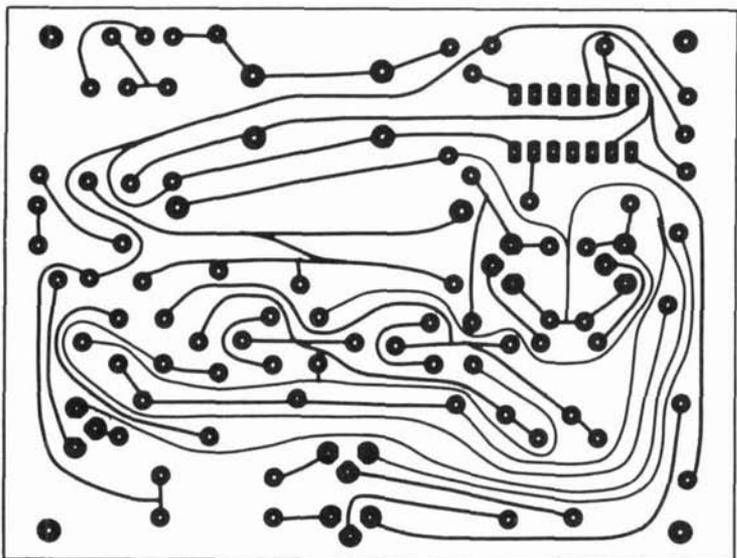
drying

The drying step is important because the photoresist must be dry to function properly but it must not be overheated.

Shipley AZ-111 photoresist can be dried in an oven at 150° F (70° C) for five minutes. Kodak KPR-2 photoresist requires 20 minutes at 170° F (80° C).

Both types can be dried under a *red-filter* type heatlamp at a distance of about 9 inches for 5 to 10 minutes, using the gentle breeze from a fan to prevent the board from getting too hot. The photoresist can also be dried with a heat

fig. 10. Connect the circuit pads with narrow black drafting tape. This is your completed printed-circuit layout transparency.



lamp while the board is being spun. With high-density boards make an effort to keep dust and lint off the work to prevent short circuits on the finished board.

exposure

The photoresist-coated board is placed in contact with the transparency and exposed to a source of ultraviolet light. The tape side goes on top unless you forgot to turn the paper over in the drafting step. To insure that the transparency and the copper-clad board are in close contact it is advisable to build a frame like that shown in fig. 12. If you don't use a frame simply place the copper-clad board on a flat surface, center the transparency, and place a sheet of glass over the combination.

A sunlamp at a distance of about one foot is used to expose the resist.* A fan should be used to keep the photoresist from getting too hot. The exposure time

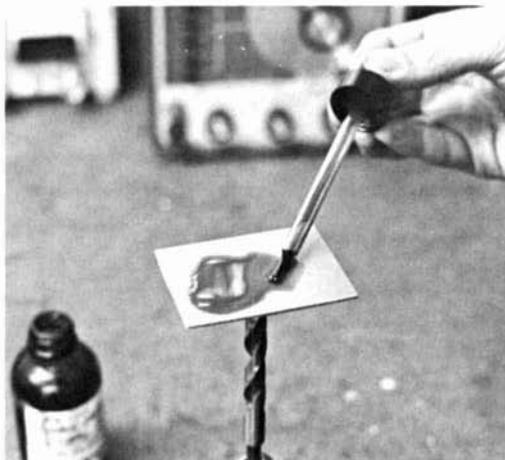


fig. 11. A thin, even coat of photoresist is applied to the board by spinning it with a drill motor.

for AZ-111 with the setup shown in fig. 13 is 15 minutes.

If you use a different ultraviolet source, a different lamp-to-board distance, or a different photoresist, you will

*The sun is an excellent substitute.

have to determine exposure times with test strips. To do this you coat a piece of scrap board with photoresist, expose it, and with a piece of cardboard, cover or uncover a new section of board every few minutes. Since glass absorbs ultraviolet light it is necessary to place a sheet of the

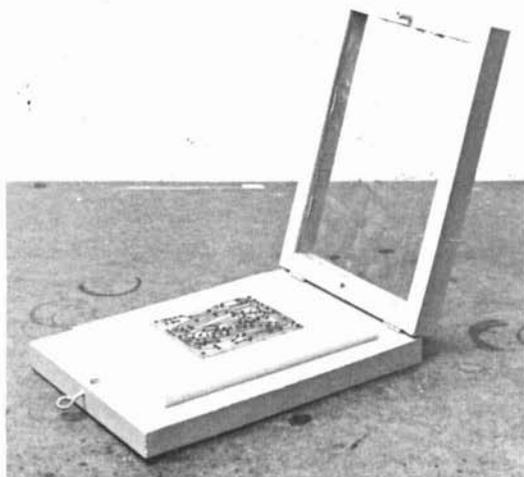


fig. 12. The circuit transparency and sensitized board are held in close contact with a home-made contact-printing frame.

same type glass between the lamp and the test strip. With a timed test strip you can quickly determine the proper exposure time for your combination of photoresist, sunlamp and lamp-to-board distance.

When choosing an ultraviolet source remember that the more the lamp resembles a point source the greater the degree of resolution. It is for this reason that fluorescent ultraviolet lamps are not completely satisfactory for highly detailed integrated-circuit work.

Room lighting is not critical for Shipley AZ-111. The dried boards can withstand up to two hours of ambient fluorescent lighting and considerably longer exposure to incandescent lighting. Other photoresists such as Kodak KPR-2 and Dynachem photoresist² are less tolerant in this respect due to their greater sensitivity.

developing

Shipley AZ-111 is developed by placing the exposed board in the developer at room temperature for about five minutes with occasional agitation. If the areas where the photoresist was intended to dissolve turn purple, your exposure was



fig. 13. Circuit board is exposed to ultraviolet lamp for about 15 minutes. Fan keeps the photoresist from getting too hot.

not long enough or your photoresist is too old.

The developer is made by dissolving 2½ teaspoons of household lye in one quart of water (15g/liter).* Use care when working with caustic solutions. After the board is developed, rinse it with cold water; it can now be etched.

Kodak KPR-2 is developed in trichloroethylene, a common dry-cleaning solvent, for about three minutes; work in a well-ventilated room. After developing, dry the board under a heatlamp for a few minutes. Do not touch the photoresist until it is completely dry (it is very soft while wet).

If you used a *negative* transparency with KPR-2 the board is ready to be etched; if you used a *positive* transparency the areas of copper you want to be etched away are covered with resist

and those to remain are bare. Since the circuit would obviously not work if the board were etched at this point it is necessary to reverse the pattern on the board. This is done by immersing the board in a commercial electroless tin-plating solution. (See later section on plating solutions.)

When this is complete the resist is stripped off with acetone and a paper towel. The areas which are to remain after etching are plated with tin while the areas to be removed are bare copper. The board is now etched in chromic acid since it rapidly dissolves copper but does not attack tin.

etching

Some of the methods used to etch printed-circuit boards, according to speed and freedom from undercutting, are

1. Spray etching
2. Bubble etching
3. Splash etching
4. Immersion with continuous agitation or stirring
5. Simple immersion with occasional agitation

Bubble etching is the most highly recommended method for amateur use as it is very fast and does not require complex equipment. In ferric chloride at room temperature a two-ounce copper-clad board requires 60 minutes to etch by method 5, 15 minutes by method 4, and only 5 minutes with bubble etching.

A bubble etcher can consist of a large ceramic aquarium aeration stone immersed in the etchant and supplied with a source of air such as that provided by a heavy-duty aquarium pump. The circuit board is placed slightly below or on the surface of the etchant and inclined so there is a good flow of etchant along the entire under-surface of the board (figs. 14 and 15). Do the etching in a well ventilated room with a damp cloth over the etching tank to catch the spray. The

*The developer is deactivated upon long exposure to the air.

spray from the chromic acid etchant is especially hazardous.

etchants

A description of most of the etchants suitable for amateur use is provided by **fig. 17**. The vertical axis is the etching rate relative to cupric chloride; the horizontal axis is the degree to which the solution has been depleted by previous etching. It can be seen that ammonium persulfate is the fastest etchant shown and that the etching rate is increased considerably by the addition of a trace of mercuric chloride.

This graph also shows that the addition of hydrochloric acid to ferric chloride results in a decreased etching rate but allows the solution to be regenerated by simple overnight aeration. Ammonium persulfate often can be purchased from local electronics suppliers or from mail order houses; ferric chloride can be purchased in liquid form from local electronics suppliers. However, all etchants

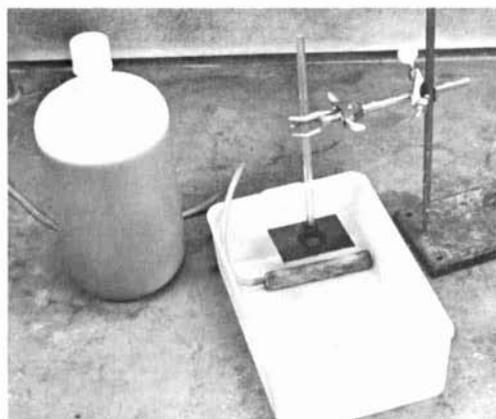


fig. 14. Circuit board is etched in large non-corrosive container. Oblong object under the circuit board is a ceramic aquarium aeration stone.

can be made much less expensively than they can be bought; the ingredients can usually be obtained from chemical supply houses in the larger cities. Buy the most inexpensive grade available, usually called *technical*.

All etchants are toxic and should not be allowed to contact the skin or eyes. Remember that you must add acid to water, not the other way around. It goes without saying that you must keep all

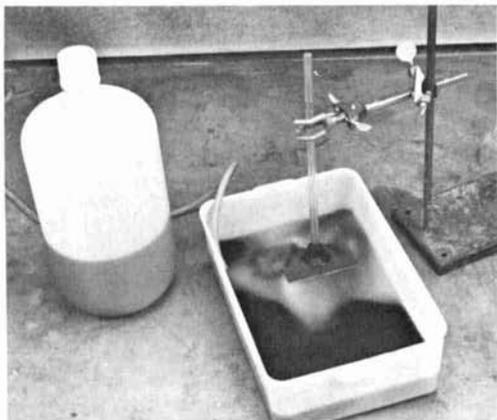


fig. 15. With the bubble etching technique the circuit board is completely etched in about 5 minutes.

chemicals out of the reach of children.

Cupric chloride is my favorite etchant. Although it is slower than the others it is less expensive and is easily regenerated. Bubbling air gently through the solution for a few hours or overnight and an occasional addition of water and hydrochloric acid results in complete regeneration of the solution. Thus, after etching a few boards you end up with more etchant than you started with.

You will note that after etching a board the cupric chloride solution is quite dark. Aeration is complete when the clear yellow-green color reappears. Add 150 milliliters of concentrated hydrochloric acid and 350 milliliters of water to the etchant after using 1 liter to etch 400 to 500 square centimeters (approximately 70 square inches) of 2-ounce copper-clad circuit board.

plating

To obtain maximum corrosion resistance and solderability the photoresist should be stripped off with acetone and a

paper towel, the copper areas cleaned gently with a cleanser, and the circuit board immersed in an electroless tin-plating bath; nickel and gold are possible substitutes for the tin. You may want to

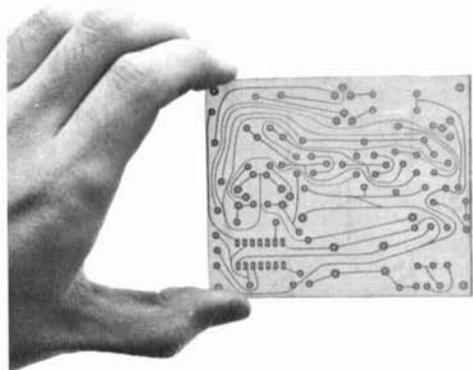


fig. 16. Completed printed-circuit board.

plate edge-connecting circuit boards with gold because of its high corrosion resistance. Unfortunately, Shipley gold- and nickel-plating solutions are presently available only in large quantities.*

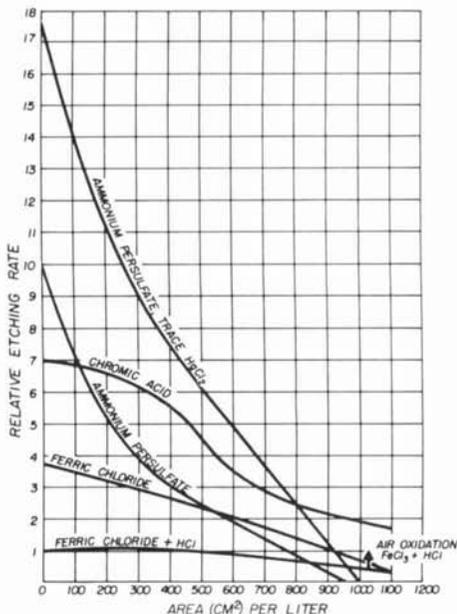
Note that if you use a positive-transparency — positive-resist or negative-transparency — negative-resist combination you may plate before resist application *or* after etching. If you don't have confidence in your abilities as a chemist and choose not to plate, leave the photoresist on since it affords good corrosion protection and makes soldering only slightly more difficult.

electroless plating solutions

Electroless plating solutions are available which will plate a variety of metals at reasonable rates onto copper and certain other metal surfaces, or onto pre-treated nonmetallic surfaces. No dc power is necessary as the solutions contain a reducing agent which chemically reduces the metal ions to the free metal at the solution-substrate interface. The

*Gold plating, Shipley EL-221 gold, \$24.50 per gallon. Nickel plating, Shipley NL-63, \$19.00 per gallon. Shipley Company, Inc., 2300 Washington Street, Newton, Massachusetts 02162.

catch to an otherwise beautiful story is that there does not appear to be an electroless tin bath which is stable, plates at room temperature, and produces a shiny, thick and pore-free deposit.



Ammonium persulfate: 240 grams ammonium persulfate per liter (plus 10 milligrams mercuric chloride)

Chromic acid: 200 grams chromium trioxide and 200 milliliters concentrated sulfuric acid per liter

Ferric chloride: 600 grams ferric chloride per liter

Ferric chloride plus hydrochloric acid: 600 grams ferric chloride plus 300 milliliters concentrated hydrochloric acid per liter

Cupric chloride: 100 grams cupric chloride plus 300 milliliters concentrated hydrochloric acid per liter

fig. 17. Etching rates of various etchants vs depletion of etchant, square centimeters of 2-ounce copper-clad board etched per liter of etchant.

A common electroless tin-plating bath which will produce a fairly shiny, if thin and porous, tin plate at room temperature consists of ½ gram (¼ teaspoon) stannous chloride, 2 grams (½ teaspoon)

thiourea, and 3 grams (½ teaspoon) sulfamic acid dissolved in 100 milliliters (½ cup) of water. Five milligrams of either alizarin or alizarin red S may be added as a brightener if desired.



Materials for an electroless tin-plating bath.

This bath is unstable and only enough should be prepared at one time to cover the surface of the work to be plated. Plating time is 10 to 20 minutes. The bath does not produce deposits thick enough to withstand chromic acid and thus is not suitable for positive-mask — negative-resist — tinplate applications. For thick corrosion-resistant tinplate you must go to electroplating or high-temperature electroless tin baths. An example of the latter is Shipley's LT-27 tin (evaluation kit, \$8.50). This bath is operated at 150-180° F with plating times of five minutes; bath makeup requires concentrated hydrochloric acid.

ground-plane circuit boards

In those instances where a good ground is necessary or where feedback may be a problem it is recommended that you use a ground-plane board. This can be done quite simply by using a two-sided copper-clad laminate and not etching one side. To prevent component leads from shorting to the ground plate it is neces-

sary to make a guard ring around each hole. This can be done either by routing with a drill or by photoresist techniques.

When working with uhf circuits it may be advantageous to combine ground-plane printed circuits with a recently introduced form of point-to-point wiring. The ground lead of a component is soldered directly to the ground plane; the other leads are connected either point-to-point, to stand-offs, or to islands of copper isolated from the ground plane. Pieces of circuit-board may be soldered edge-on to the ground plane to serve as shields or as mounts for coil forms and variable capacitors.

materials

There is a considerable amount of high quality double-sided G-10 copper-clad board on the surplus market. Don't buy new printed-circuit board unless you are willing to pay about three times the cost of surplus material.

Kodak photoresists are available from local Kodak distributors (\$14.30 per quart for KPR 2). Kodak Autopositive photoresist type 3 (KAR 3) is a positive-working photoresist comparable to Shipley AZ-111. (KAR 3 is \$24.55 per quart; developer is \$3.95 for 2 gallons.)

Shipley AZ-111 photoresist can be obtained from S&H Electronics* in quantities of 1 fluid ounce for \$2, or direct from Shipley for \$22 per quart. Large radio clubs might buy a quart and distribute the material to the membership. The shelf life of AZ-111 is one year at room temperature, two years if refrigerated. (Do not store in your home refrigerator if you have children who might mistake the photoresist for steak sauce.)

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*S&H Electronics, Post Office Box 286, Corvallis, Oregon 97330.

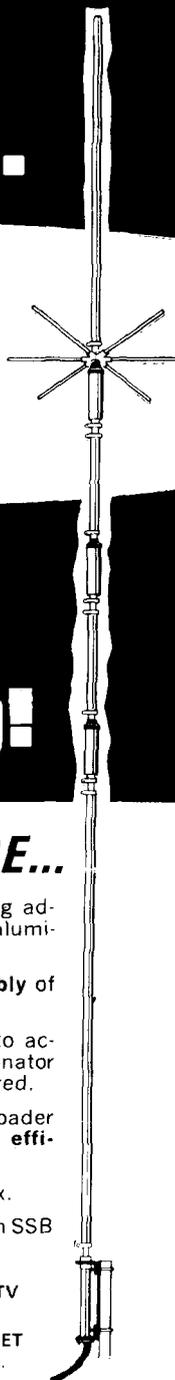
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top-loaded vertical for 80 meters

Ideas and
construction notes
for a popular version
of the 1/4-wave
vertical antenna
using a
capacitive hat
for top loading

Henry G. Elwell, Jr., W2MB, 392 Lafayette Avenue, Westwood, New Jersey 07675

The purpose of this article is to pass along my experiences and some ideas on the evolution and construction of an 80-meter top-loaded vertical antenna. To keep things in chronological order, I'll start with the simple vertical wire I first put up. It consisted of a 60-foot length of no. 12 wire suspended from an insulator attached to the limb of a tree. The top of this antenna was 65 feet above ground.

ground losses

All antenna literature states that a good ground system is necessary for a base-excited $\frac{1}{4}$ -wave vertical. Therefore I laid out 24 radials around the antenna base. Each radial was no. 12 wire 66 feet long. But is this a good ground system for 80 meters? I thought so, and friend W2LV agreed it was the best I could do under my circumstances. However, W2LV kept mentioning ground losses and finally provided the information in **table 1**. This data doesn't exactly fit my case, but it is representative and based on a vertical radiator of 0.2 wavelength. The data goes back to the 1930s when broadcasters were interested in standard: for antennas with vertical propagation angles.

The interesting thing about the data is that if the radials are too short, say 0.1 λ wavelength, they don't do much good.

impedance matching

Using a GR 916A rf bridge, I made measurements between the antenna and ground system. Antenna characteristics are shown in fig. 1. A pure resistance of 57 ohms appears at 3.65 MHz. I wanted the antenna to resonate at 3.8 MHz, but at this frequency the impedance was 63 + j36 ohms, which is equivalent to an swr of 2. This indicated that some kind of matching arrangement was necessary.

The series-resonant circuit shown in fig. 2A was constructed and installed in a plywood box, then mounted on a short post at the bottom of the antenna wire. The 50-ohm tap point for the coax cable was determined using a homemade bridge.¹ A point on the coil producing a zero indication could not be found, so the arrangement of fig. 2B was used. The tap and capacitors were carefully adjusted to give a null. (Incidentally, I found from experience that it's prudent to check an impedance bridge with a carbon composition resistor to make sure everything is working properly.)

The transmission line was connected, and the transmitter was fired up. An swr of 1.2 (at 3.8 MHz) was obtained at the transmitter end with an swr bridge.

fig. 1. Measurements of the initial 80-meter $\lambda/4$ -wave vertical suspended from a tree limb. Desired resonant frequency was 3.8 MHz.

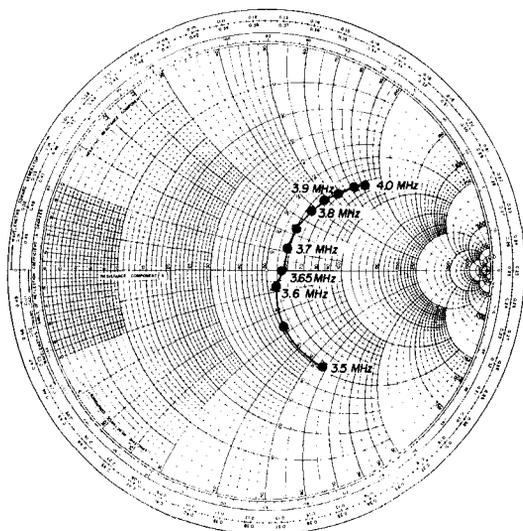


table 1. Ground loss in radials for vertical antennas.

no. radials	radial wavelength	percent ground loss
30	0.4	23
30	0.15	41
60	0.4	10
60	0.15	38
120	0.4	2
120	0.15	35

Results were interesting. Close-in signals (200-300 miles) were weak on the vertical compared to a horizontal antenna. Signals further away were about equal in amplitude on either antenna. DX signals (Europe, Hawaii) were stronger on

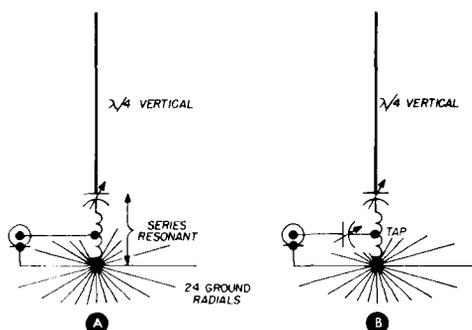


fig. 2. Tuned circuits for resonating the initial version of the vertical. Circuit at B produced an swr of 1.2 at the desired operating frequency.

the vertical. I worked 23 countries on 80-meter phone in the 1969 ARRL DX test with the vertical.

top loading

Flushed with success, my next objective was to improve the efficiency of the vertical by moving the current loop away from ground. Top loading seemed to be the answer.

After reading the early articles^{2, 3, 4} the installation shown in fig. 3 evolved. Although top loading can be accomplished with a ball, cylinder, or disk, the latter seemed the easiest to build. A chart² of capacitance vs. disk diameter showed that a disk six feet in diameter would give a capacitance of 61 pF. The only reason I picked six feet was that it was a nice

number and I felt the bigger the better. I had reason to regret this decision, which I'll now explain. You'll notice from fig. 3 that a pulley arrangement is used to raise and lower the antenna. Such a method is convenient and saves climbing during tuning adjustments. However, be sure the vertical path is free of obstructions for the whole diameter of the disk! I had a fearful journey up the tree cutting down branches which criss-crossed the six foot imaginary cylinder through which the disk has to pass. There were times when I wished that a 1-foot-diameter disk had been used.

capacitive hat

The disk was made by using two six-foot lengths of 1 x 2 inch wood in the form of a cross. A circle of 1/4-inch copper tubing was supported on standoff insulators at the ends of the cross; and 24 no. 12 wires were connected from the outside to the center of the disk (fig. 4).

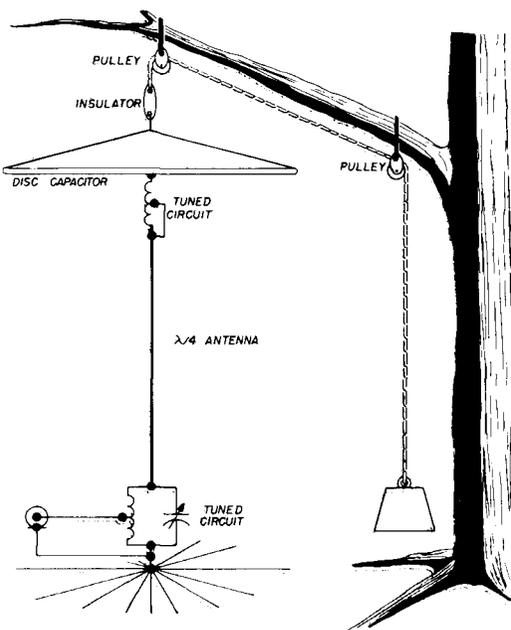


fig. 3. The antenna with a capacitive hat for top loading. The disk was six feet in diameter, but a smaller disk could have been used with a larger tuning inductance.

loading inductance

Knowledge of the disk capacitance is necessary to obtain a ball-park figure for the loading-coil inductance. An inductance of 20 μH was required to resonate the system at 3.8 MHz with the 61-pF disk.

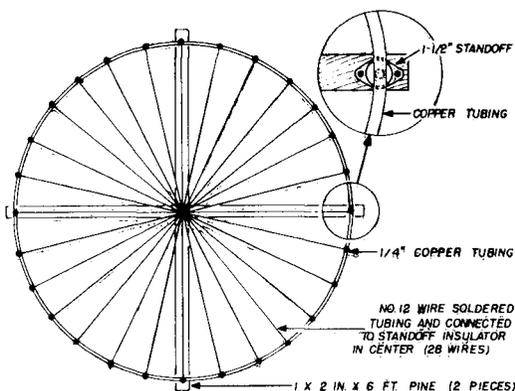


fig. 4. Construction details of the capacitive hat. The copper tubing is flattened and attached to a standoff insulator as shown in the inset.

The coil was from some surplus equipment. It has a 3-inch-diameter ceramic form with 33½ turns of no. 12 wire spaced the diameter of the wire, with an overall inductance of 44 μH . This coil, with provisions for shorting out turns, was mounted as shown in fig. 3 and the whole thing hoisted in the air.

Now, how do you tune the coil to bring the antenna into resonance at the desired operating frequency? The old QST articles stated that the field strength of the antenna should be monitored at a distance greater than 300 feet. A point is reached when decreasing the coil inductance causes the field strength to drop off. You then go back a few turns and there you are.

Such a method works but it doesn't seem very scientific. Since I had an impedance bridge available I decided to do it properly.

Unfortunately the impedance bridge

measured only to about 1200 ohms, and the base of a properly tuned top-loaded vertical is probably several thousand ohms. It was necessary to have some means of using the bridge while adjusting the coil turns to produce a pure resistance at the base of the antenna, which would be in the range of the rf bridge. If

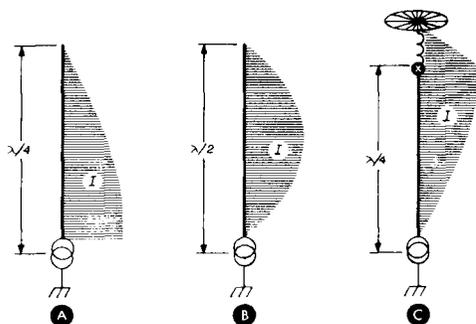


fig. 5. Current distribution on three vertical antennas. The tuned circuit at C simulates $\frac{1}{2}$ wavelength.

a pure resistance is obtained at the antenna base, the antenna is in resonance.

measurements

Let's pause a minute to look at the problem. Fig. 5 shows several conditions of current distribution. A is that of the quarter-wave vertical, B a half wave vertical, and C a top-loaded quarter-wave vertical to simulate a half wavelength. If we could put our measuring equipment at the top of the antenna, a low-impedance point would be available at point X; not very practical.

W2KXD pointed out that the same objective could be accomplished at ground level by using a quarter-wave extension as shown in fig. 6. The quarter-wave coax will translate the high impedance at the antenna end to a very low impedance at the bridge end of the coax. The bridge measurement will show a pure resistance when the antenna is at resonance. I believe this method of tuning the coil of the top-loaded vertical is novel.

Don't let the mention of a General Radio rf bridge scare you off if you don't have one available. The rf bridge described in Reference 5 will work very well. The quarter-wave coax length was determined by measuring its input with the output open circuited, and cutting until a pure resistance input was obtained. Before connecting the antenna, I took the precaution of inserting a 50-ohm carbon composition resistor across the bridge. It read 49.5 ohms, so I knew my setup was correct. With the total coil in use, a reading was taken at 3.5 and 4.0 MHz with the following results:

$$3.5 \text{ MHz } Z = 1.0 + j0 \text{ ohms}$$

$$4.0 \text{ MHz } Z = 1.5 + j 12.1 \text{ ohms}$$

The pure resistance at 3.5 MHz indicated that the antenna was resonating at that frequency, but 3.8 MHz was desired.

The antenna was lowered and eleven turns shorted out on the coil. After pulling the antenna back into place, the measurements then became:

freq (MHz)	impedance (ohms)
3.5	1 - j7.1
3.6	1.3 - j4.2
3.7	1.3 - j2.7
3.8	1.7 - j0
3.9	1.7 + j2.7
4.0	1.5 + j5.0

Resonance is indicated at 3.8 MHz, just where I wanted it. To further test the procedure, 23 turns were shorted out with the following results:

freq (MHz)	impedance (ohms)
3.5	2.5 - j11.4
3.6	2.0 - j9.7
3.7	2.2 - j4.0
3.8	2.3 - j2.6
3.9	2.2 - j2.0
4.00	2.2 - j1.2

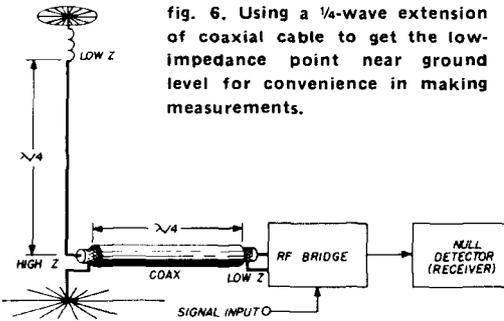
It can be seen that resonance is above 4.0 MHz. Therefore the 11-turn tap point was correct.

Since there was now a high impedance at the base of the antenna, a parallel-tuned circuit was used as shown in fig. 7 and adjusted as previously described.

After reconnecting everything, the transmitter was fired up. The swr bridge at the transmitter end showed the following readings:

frequency (MHz)	swr
3.5	almost full scale
3.6	3.3
3.7	1.4
3.8	1.2
3.9	1.5
4.0	3.0

A check on the receiver showed that locals were way down compared to those on the half-wave horizontal, and equal



signal strength between the two antennas appeared to be at about 1000 miles. The vertical was used on 80 meters during the 1969 phone CQ DX contest with good results. I had the intuitive feeling, however, that I could work DX stations just as well with the half-wave horizontal, because received signal strengths seemed to be the same. It was not working the

way I had hoped it would, and I wanted to do some more testing.

current distribution

One nice thing about having a project and friends is the interesting discussions one can get into. W2LV suggested that I get rid of the coil and just use the disk,

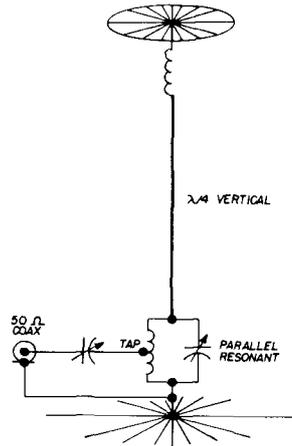


fig. 7. Parallel-resonant circuit for tuning the final configuration.

his feeling being that the coil is a loss unless it's wound with 1/4-inch copper tubing, silver plated.

W2LL suggested that I solder a bunch of Christmas tree lights along the antenna and see if the current distribution was correct, then I could leave them up for the holiday season.

One never knows quite when to believe W2LL, but his suggestion fired my imagination. A dozen 2-volt, 60-mA bulbs were purchased and spaced every five feet along the 60-foot wire. There was some discussion on how far to tap the bulbs across the wire, but little objection to my suggestion of 5 inches. Having the antenna on the pulley made it easy to lower it, disconnect it, roll it up, and take it indoors to work on. The next evening, with the bulbs in place, the antenna was reconnected and hauled into position. It took 1 kW of power to light the lamps to proper brilliancy.

final adjustments

I looked at the lights from all angles and several distances, trying to figure out a way to record their brilliance quantitatively. How do I get at a point equally distant from each light? Can I photograph them?

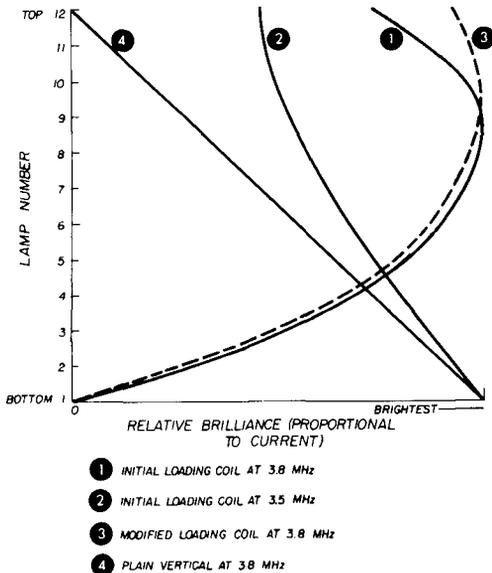


fig. 8. Results of tests using small lamps to determine current distribution.

The final solution was to pick out the brightest lamps, and those above and below that point were grouped as to equal brilliance. Very crude of course; but if you are there, you know what's happening. A plot of what I saw of the current distribution on the top-loaded $\frac{1}{4}$ -wave vertical antenna is shown in fig. 8 for 3.8 MHz. The lamps at 1 show a current loop about $\frac{3}{4}$ of the way to the top of the antenna. The transmitting frequency was increased to 4.0 MHz with results approximately the same. The transmitter frequency was then reduced to 3.5 MHz, and the lamps assumed a relative brilliance as shown by 2.

The next step was to lower the antenna, short out the total loading coil, and

pull up the antenna. With the transmitting frequency returned to 3.8 MHz, the relative current distribution appeared to be as at 2.

The light presentations for the different displays agree with theory except for the 1 readings; the maximum brilliance should be at the top.

Down came the antenna, and coil removed. The coil Q measured 290 and had an inductance of $23 \mu\text{H}$. (The same coil with the shorted turns unshorted had a Q of 400 and an inductance of $44 \mu\text{H}$.)

Turns were removed from the coil to return its inductance to $23 \mu\text{H}$. This not only improved the Q of the coil by eliminating the shorted turns, but improved its form factor as well. The final Q of the coil at 3.8 MHz was 480; a 165% improvement over the original value.

The coil was reinstalled in the antenna and the lights inspected. The dashed line, 3, of fig. 8 shows the improvement in the current distribution. I have no doubt that W2LV is correct in suggesting the use of $\frac{1}{4}$ -inch copper tubing for the coil — or better yet eliminating it — but the improvement one way or the other seemed marginal.

conclusions

I've attempted to pass along my experiences and some ideas on the evolution and design of an 80-meter top-loaded vertical antenna. You might say that my results were inconclusive since top loading gave no better results than base loading. However, top loading does get the current loop at the highest point of the antenna. If that's what you want, now you know how to do it.

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ham radio

frequency synchronization for scatter-mode propagation

A frequency standard
that can be used
by vhf/uhf stations
to precalibrate
receiving systems

Vhf and uhf stations attempting to communicate via the more exotic types of propagation (meteor scatter, moonbounce, tropo scatter, etc.) require close synchronization in two areas: time and frequency.

the frequency sync problem

Time synchronization is generally not a problem. WWV, CHU, and other sources provide a time reference accurate enough for most communications. Accuracy of the receiving and transmitting frequencies is quite another matter, however.

Most moonbounce and meteor scatter work requires an extremely narrow i-f bandwidth (100-500 Hz) to enhance the effective signal-to-noise ratio of the re-

ceiving system. Setting this extremely narrow window accurately on the desired receiving frequency is difficult at best. At 432 MHz, 100 kHz represents a frequency accuracy of 2×10^{-5} percent! Most standard crystal calibrators or signal generators have inherent accuracies at least 100 times worse than this, not considering temperature variations. In addition, most receiving systems use at least one frequency conversion with a crystal-controlled local oscillator, resulting in another frequency error; namely, the accuracy and frequency stability of the crystal in the converter local oscillator. Multiple frequency conversion systems, commonly used above 420 MHz, are proportionately worse. Even a well-equipped vhf-uhf amateur station has the capability to calibrate only the station receiver, not the entire receiving system. As a result, most scatter-mode communication failures occur because one station or another is listening on the wrong frequency! This has happened on occasion to even the most proficient operators.

temperature compensation

One possibility that comes to mind is to temperature compensate all frequency-determining components in the system and perform a one-time calibration, assuming all components do not drift or age with time or temperature. Experience has shown this to be a poor assumption;

James A. Buscemi, K2OVS, A1L, A Division of Cutler-Hammer, Inc., Deer Park, New York

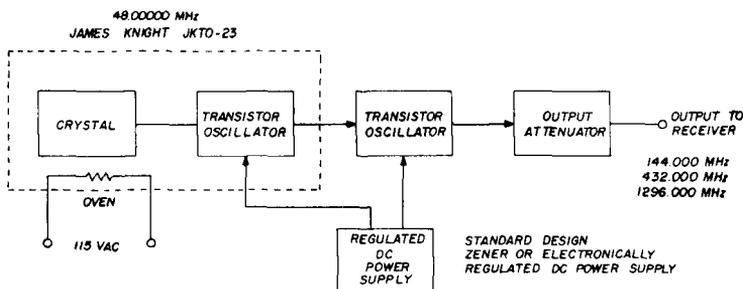
periodic recalibration of all test and measuring equipment is standard practice in industrial and military establishments. In addition, most amateurs don't have access to frequency counters or sophisticated lab equipment.

frequency standard

Some sort of periodic frequency-calibration method is therefore necessary

sensitivity or antenna testing. A calibrator such as this is a worthwhile accessory and could, theoretically, be adjusted to extreme accuracy by comparison with an NBS traceable standard. However, individual construction and use of a similar calibrator would only introduce additional errors between stations (even commercial standard frequency counters have been known to drift out of calibration).

fig. 1. Suggested frequency standard for vhf/uhf moonbounce and tropo scatter work. Unit would be used by participating stations on a sharing basis to assure frequency synchronization before scheduled contacts.



for stations involved in moonbounce or meteor scatter work. A frequency-standard source is a necessity; a typical source is outlined in fig. 1. This frequency standard is crystal controlled, temperature stabilized and compensated,* and voltage regulated to provide extremely stable frequency markers on 144, 432 and 1296 MHz. A James Knight type JKTO-23 oscillator module at 48 MHz provides the basic frequency stability. The oscillator alone produces enough output to calibrate most receiving systems on these frequencies and allows calibration of the transmitting frequency by comparison on the station receiver. The addition of amplifier, multiplier and/or attenuation stages is optional, depending on individual needs and desired flexibility.

other uses

If calibrated on a power-output basis, the unit may also be used for system

*Readers wishing to build their own crystal ovens will find an interesting proportional temperature control scheme in reference 1. editor.

Therefore, since most moonbounce, meteor scatter, and tropo work is generally conducted on a schedule basis between a small number of stations whose operators are known to each other, it is proposed that *one particular frequency standard* be constructed and circulated via parcel post among these operators immediately before planned schedules. Each operator could then use the same standard to calibrate his receiving (and transmitting) equipment before the schedule, thus increasing his chances of success.

Even if the standard had some long-term frequency drift, the stations using it would still be on the same frequency, regardless of whether that frequency were 432.0001 or 431.9999 MHz.

I hope the foregoing proposal will be of value to fellows involved in vhf/uhf work and promote more successful contacts on the bands above 144 MHz.

reference

1. J. A. Koehler, VE5FP, "Proportional Temperature Control for Crystal Ovens," *ham radio*, January, 1970, p. 44.

ham radio

high power injection lasers

More on the
characteristics and
driving requirements
of these
remarkable
little lasers

With the continuing crowding of the radio spectrum it is likely, indeed probable, that forms of communication more esoteric than radio will eventually have a genuine usefulness to the amateur. Likely contenders are millimeter waves and optical links; the latter category is already within easy reach of today's amateur. It is the purpose of this article to review in detail some of the important characteristics of the diode laser and to provide some circuit information for driving high power units.

characteristics

Laser diodes are moderately expensive and relatively fragile electrically. Invented at almost the same time by three different research laboratories (GE, IBM and MIT) in the fall of 1962, the first devices were formed by the diffusion of zinc into n-doped wafers of gallium arsenide (Ga-As), the material still most commonly used for semiconductor lasers.

Mechanical polishing of GaAs ingots or cleavage along crystalline planes (the preferred technique for commercial devices) produces the two end mirrors necessary for formation of the lasing cavity. Lasing occurs when electrons which have been stimulated to a high energy level to cross the pn junction fall back to the ground state. In the process their stored energy is given off as a photon of light (though other emissions may occur on a less frequent basis).

The emission of photons may be stimulated by other photons, hence setting up a chain reaction situation and the condition of *stimulated emission*. It is the stimulated emission of radiation that results in the production of quasi-coherent light.

Since the laser diode has very high gain the length of its cavity may be very short — only 10 or 15 thousandths of an inch. This is fortunate as the threshold for lasing, which is dependent on the

Forrest M. Mims, 6901 Zuni SE A-12, Albuquerque, New Mexico 87108

diode's surface area, would be prohibitively high if a lengthy cavity were required for proper operation.

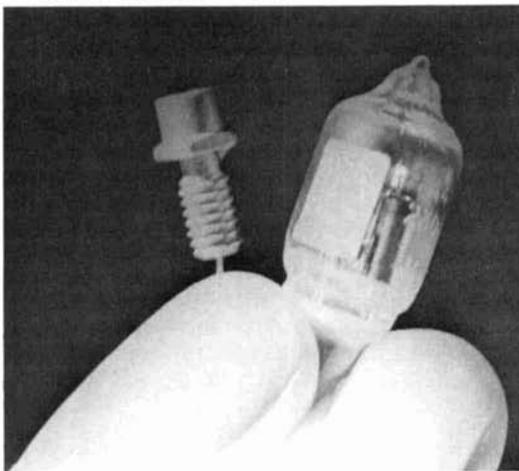
Though there are many possible configurations for experimental laser diodes commercial devices are either diffused or epitaxial. Epitaxial devices consist of two structures, homojunction and heterojunction. As the name might indicate the former is a straight GaAs epitaxial diode. The heterojunction, however, is formed with one side of the junction being composed of gallium aluminum arsenide (GaAlAs) a material similar in characteristics to GaAs.

Since the index of refraction of GaAlAs is higher than that of GaAs light radiating from the junction is subjected to a waveguiding effect with a resultant increase in laser efficiency. The magnitude of this increase in efficiency can be illustrated by comparing the lasing threshold for a diffused and a heterojunction laser, typically 100,000 amps/cm² and 10,000 amps/cm², respectively.

cw lasers

One device which is still in the laboratory is the double heterostructure laser.

Both injection lasers (left) and Krytron tubes (right) are quite small. The laser shown here is an RCA TA7699, a moderately high-power unit with typical optical output of 23 watts.



Invented at Bell Telephone Laboratories in the summer of 1970, this is the first semiconductor laser to operate continuously at room temperature. A significant lowering of the lasing threshold to 2,000 amps/cm² resulted in this achievement. As the name implies, the double heterostructure device has a layer of GaAlAs on either side of a central GaAs region. The enhanced waveguiding effect of the two GaAlAs layers helps to lower the lasing threshold.

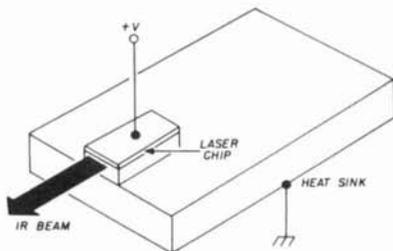


fig. 1. A typical injection laser is mounted as shown here. Infrared energy emerges from one of the parallel reflecting ends.

Though the new cw-at-room-temperature devices are not yet available commercially, their development is reported here because of their obvious application to voice communications. The ease with which these devices can be modulated greatly reduces the complexity and expense of both driving and receiver circuitry.

Like most semiconductors, laser diodes are sensitive to extremes of temperature and operating current. The lasing threshold is greatly dependent on temperature as shown in fig. 2. The sometimes subtle change from room to outdoor temperature can reduce the lasing threshold to the point where degradation can occur if the laser is operated at a current level suitable to the former condition.

Engineers at Holobeam, Inc. have designed a laser voice communicator with a feedback loop incorporating a thermistor in intimate contact with the laser to alleviate the problem. The thermistor

senses temperature changes and reduces laser current appropriately when temperature decreases.

high-current drivers

A previous article in *ham radio* provided information on driving lasers with a low to medium operating current.¹ However, lasers are currently manufactured by several companies which require 150 or more amperes for optimum operation. IBM has one single laser diode which radiates as much as 50 watts peak optical power from each end when driven by 300 amp pulses (100 nsec pulse width).

Though laser arrays capable of delivering up to 300 watts are available off the shelf from both RCA and Laser Diode Laboratories (and other companies as well) the ease with which a single diode laser may be collimated makes high power devices attractive candidates for long-range optical communication experiments.

It is difficult to design semiconductor drivers for producing currents greater than 100 amps. Hunt has mentioned SCRs that can switch currents of this magnitude;² and Brown, *et al* have presented an interesting driver consisting of a parallel arrangement of avalanche transistors which produces 200-amp pulses.³

An elegant solution to the problem of generating high current pulses is the miniature cold-cathode krytron (which

should bring a chuckle from the anti-semiconductor club). Krytrons* achieve extremely rapid switching times when discharge is initiated between cathode and anode. The discharge, which propagates through a gas under low pressure, is normally initiated by a positive pulse on the grid.

The circuit shown in fig. 3, which is similar to one developed by Sullivan, is capable of delivering pulses with an am-

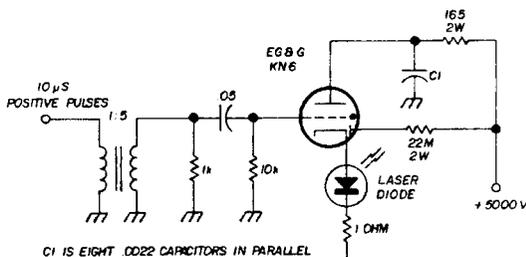


fig. 3. 2000-amp injection laser driver. Keep all leads carrying high current as short as possible. A unijunction-transistor oscillator will provide the positive-going input pulses.

plitude of up to 2,000 amps!⁴ In operation, the eight 0.002- μ F capacitors are charged through a resistor of several hundred thousand ohms until the krytron is triggered *on* by a positive pulse at the grid. The high voltage stored in the capacitors is then dumped through the krytron, laser and the 1-ohm resistor. The resistor permits the 50-nsec pulse to be monitored with a fast oscilloscope (since the resistor's value is 1 ohm, volts displayed on the scope equal current in amps through the laser).

Because of the inductance contributed by component lead lengths the pulse generator discharge section is actually an RCL circuit. To optimize the circuit's pulse shape L should be decreased as much as possible by reducing lead lengths to the absolute minimum. Otherwise the circuit's pulse will include negative components, be quite ragged in appearance and quite likely be lengthened.

*Made by EG&G, 160 Brookline Avenue, Boston, Massachusetts 02215.

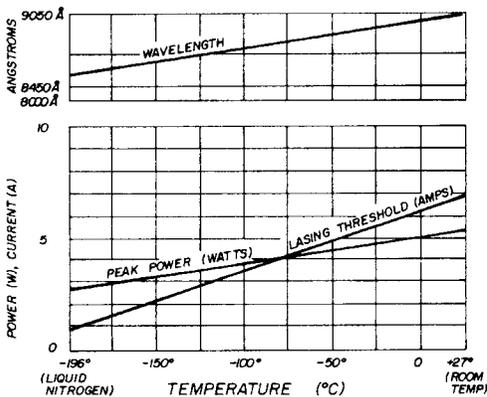


fig. 2. Effect of temperature on injection laser characteristics.

Of course, 2,000-amp pulses are overkill when it comes to driving lasers requiring from 100 to 300 amps. Peak current can be reduced to these lower values simply by lowering the charging voltage and/or slightly increasing the resistance of the current monitor. Peak current can be calculated from known component values, but because of the significant influence of undesirable strays, it is helpful to make actual current

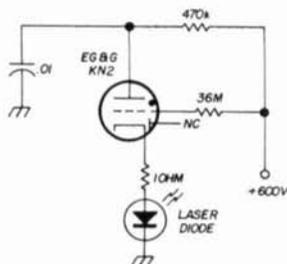


fig. 4. General-purpose injection laser driver. Keep all high current carrying leads as short as possible.

measurements with an oscilloscope using a conventional junction diode for a load. (To protect the laser diode it should be connected into a driving circuit *only* after peak current is known.)

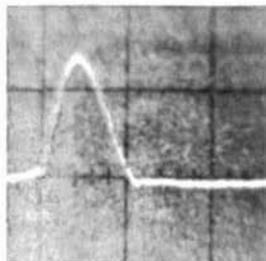
The circuit in fig. 3 may be operated at pulse repetition rates of up to 1000 Hz. Although fig. 3 is preferred for applications requiring current adjustments, such as when a variety of lasers are to be used, the circuit in fig. 4 is perfectly adequate for experimental work. Adapted from a design by Koechner,⁵ the circuit is a simple free-running relaxation oscillator. Positive bias on the grid pre-ionizes a portion of the gas in the krytron and prepares the tube for firing. When the voltage stored in the 0.01- μ F capacitor becomes sufficiently high to fire the krytron, the capacitor discharges through the tube, the 1-ohm resistor and the laser diode. The 1-ohm resistor serves as a current-monitoring point as in the previous circuit.

With the values shown in fig. 4 the circuit will produce a 50 nsec, 75 amp

pulse at a repetition rate of about 200 pulses per second. If lead lengths between all components carrying the current pulse are kept short very clean pulses will be obtained. The circuit is ideal for driving moderately high power single laser diodes; suitable alterations of appropriate component values will permit very high power single lasers, such as the IBM series and the RCA TA7705 and TA7787, to be driven as well. Modifications are easily accomplished with the help of a fast oscilloscope. Serious experimenters would be well advised to consult Koechner's very complete paper for additional help; his theoretical treatment is excellent.

power supplies

I have had good results operating both circuits with a miniature dc-dc converter. There are numerous ways of designing and building dc-dc converters; with the



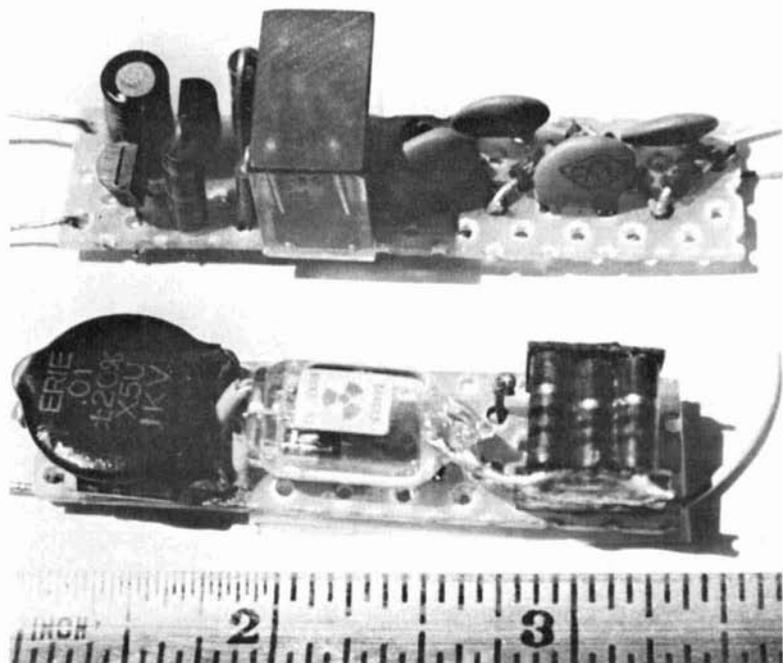
The circuit of fig. 4 yields an excellent pulse. Calibration is 100 nsec per horizontal division and 50 amps per vertical division.

numerous references available there is no need to describe a particular circuit here. Suffice it to say that a transistorized blocking oscillator with an appropriate step-up transformer followed, perhaps, by a voltage multiplier will permit a krytron laser driver to operate from a small 3-volt battery.

High-voltage photoflash batteries may be used to obtain the several hundred plus volts necessary to operate a laser driver, but the miniature size of the dc-dc converter makes it a very attractive power source, particularly for field experiments.

Additionally, the dc-dc converter is a one-time investment in contrast to high-voltage batteries. Regardless of the power source you choose be sure to follow all precautions that normally apply to high voltages. Size is deceiving — batteries and miniature dc-dc converters are capable of delivering healthy shocks.

With an impressive background of military contracts in the semiconductor laser business RCA offers, at present, the best buys for the experimenter in high-power single laser diodes. For low- to moderate-power lasers, try any of the companies except IBM. By the way, don't hesitate to write to the manufacturers for more



Injection laser drivers and power supplies can be easily miniaturized. The dc-dc converter (top) can supply up to 600 volts and will operate the laser driver (below) when powered by a 3-volt battery. The cube of 0.1-ohm resistors provides an especially low-inductance current monitor. These units were developed by the author for use in a small rocket.

parts suppliers

Only a few companies manufacture laser diodes for commercial sale. Low- to moderate-power lasers are made by Laser Diode Laboratories, RCA, and Texas Instruments.* Monsanto no longer manufactures lasers, but according to its latest data sheets still stocks several types. Sperry makes a relatively low cost laser, but production was halted as this article was being written. High-power single laser diodes are made by IBM and RCA. High-power arrays which generally do not require very high driving currents are made by Laser Diode Laboratories and RCA.

information; most of them will gladly supply very good data sheets and price and delivery schedules.

For practical communications experiments a simple lens arrangement is neces-

*Injection lasers are manufactured by: IBM Corporation, Federal Systems Division, 18100 Frederick Pike, Gaithersburg, Maryland 20760; Laser Diode Laboratories, 205 Forrest Street, Metuchen, New Jersey 08840; Monsanto Company, Electronic Special Products Division, 10131 Bubb Road, Cupertino, California 95014; RCA Electronic Components, 415 South Fifth Street, Harrison, New Jersey 07029; and Texas Instruments, Inc., Semiconductor Components Division, Post Office Box 5474, Dallas, Texas 75222.

sary to collimate the laser beam. RCA has an excellent brochure⁶ which touches on optics. Edmund Scientific Company (600 Edscorp Building, Barrington, New Jersey 08007) stocks a wide variety of plano-convex and double-convex lenses which will permit the fairly broad beam from a laser to be narrowed to a few tenths of a degree. To capture all the light emitted by a typical laser choose a lens whose focal length is approximately equal to its diameter (near f/1 as possible).

Laser receivers are discussed in some detail by Campbell in his earlier article on injection lasers. There are numerous technical articles and references on the subject of detecting light — but keep in mind that the laser's light pulse peaks in the infrared and is quite narrow in time. Silicon detectors are admirably matched to GaAs lasers spectrally, and special types respond well to very fast pulse widths.

conclusion

Very few radio amateurs are experimenting with lasers of any kind, much less semiconductor lasers. The field is young — essentially wide open — and the time is ripe for amateurs with a pioneering instinct to become involved in the field of optical communications. The challenges are many (working with invisible light takes getting used to) but the rewards are great. In fact, it is quite likely that radio amateurs will make important contributions to this very important field of communications.

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ham radio



DIODES

PIV	TOP-HAT 1.5 AMP	EPOXY 1.5 AMP	EPOXY 3 AMP	STUD- MOUNT 6 AMP
50	.04	.06	.12	.15
100	.06	.08	.16	.20
200	.08	.10	.20	.25
400	.12	.14	.28	.50
600	.14	.16	.32	.58
800		.20	.40	.65
1000		.24	.48	.75

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september 1971  33

mobile fm sequential encoder

This
sequential encoder
provides complete
dial control
of your local
fm repeater

John S. Hollar, W3JJU, 377 Rumson Drive, Harrisburg, Pennsylvania 17104

A **stable pulsed encoder** for controlling fm repeaters is a relatively simple device requiring only a few components and a telephone dial. Since more and more fm repeaters are using pulse-type decoders and additional control it is convenient to have a small pulse encoder on hand whenever you need it.

The pulsed encoder in **fig. 1** uses lowcost parts, is easy to build, and provides an excellent sequential encoder for mobile fm operation. The full-size printed-circuit board in **fig. 2** reduces construction time to a few hours.

All components except the toroid oscillator coil should be available at your local parts store. Although I used a 2-Henry toroid in the circuit in **fig. 1** the surplus 88-mH toroids used by RTTY enthusiasts will do an excellent job if you juggle the values of the tone determining capacitors.

The circuit in **fig. 1** consists of a 2805-Hz oscillator (Q1), buffer stage (Q2) and emitter follower (Q3). The oscillator tone is set to the desired frequency by adjusting the .068 μ F capacitor marked with an asterisk. In some cases it may be necessary to put two capacitors in parallel to obtain the desired tone.

The 3-second hold circuit (Q4) provides a 3-second carrier and tone at the end of the pulsing sequence. This allows for selective calling of a control pulse with "hands off" capability. I used an Allied 12-Vdc dpdt relay with a coil resistance of approximately 560 ohms at K1. This is not critical however, and almost any 12-Vdc relay will work. Transistor Q4 heats up a little, but since

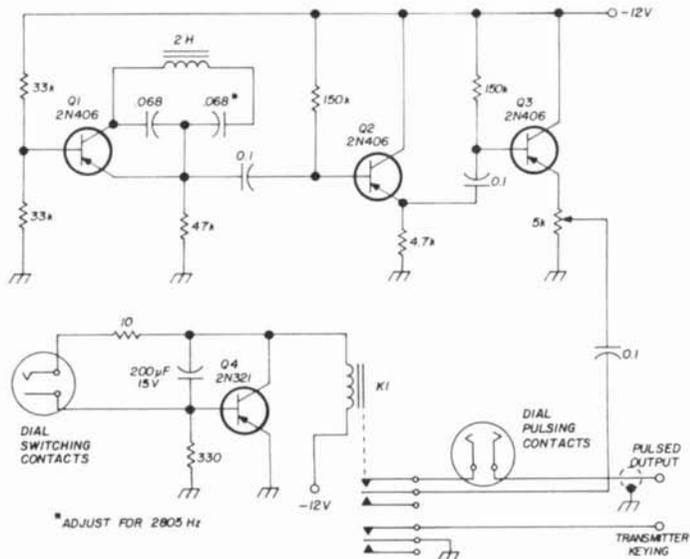


fig. 1. Circuit for the portable sequential encoder. Relay K1 is a 12-Vdc relay with dc resistance between 240 and 560 ohms.

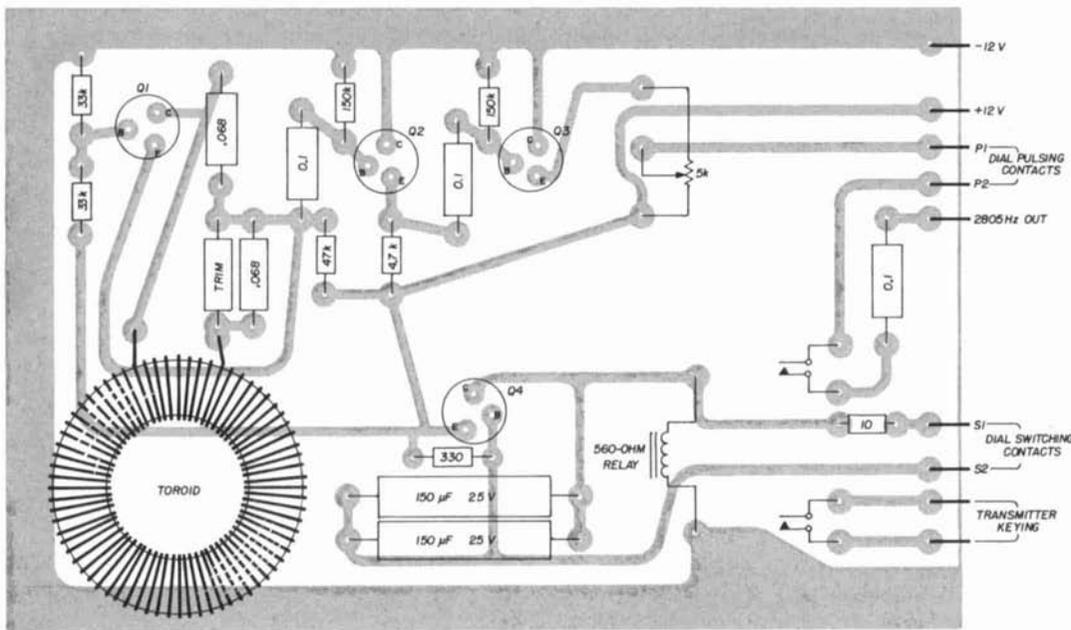
control is not continuous it is not necessary to use a heavy-duty transistor.

If you use this circuit without a separate power supply (a 9-volt transistor radio battery will work), you must bypass circuit ground or *tone low* through a 0.1 μ F capacitor to isolate the positive volt-

age from system ground. Since the circuit is open (no tone) until it is dialed and the relay picks up, the unit can be connected directly across the microphone input of your transmitter. The output matches the inputs of most fm transceivers (except those with carbon microphones).

ham radio

fig. 2. Full-size printed-circuit board and component layout for the sequential fm encoder.



a stable, variable-output weak-signal source

Receiver alignment
generator,
frequency standard,
neutralization
signal source
are just a few
uses for
this instrument

A necessary adjunct to any test-equipment bench is a stable weak-signal source. This device is basically a crystal-controlled signal generator with an adjustable output. Its applications are analogous to the tunable signal generator, but it can be a much more useful tool than either a signal generator or a crystal calibrator by combining the properties of both. Several vhf signal sources have been described in *ham radio*^{1, 2} and *VHFer*.³ All either lack frequency stability as the output is varied, or else they have too low output at the higher harmonic frequencies. The unit shown in **fig. 1** uses a pair of inexpensive RCA 40673 dual-gate mosfets to eliminate these shortcomings.

circuit description

The addition of a crystal-selector switch, S1, allows the choice of frequencies from 1 through 10 MHz. Presently, my unit uses 1 and 3.5 MHz for the high-frequency range and 8.0 MHz, 8.222 MHz, and 8.333 MHz for frequencies from 50 through 1296 MHz. High harmonic output is assured by the use of an H-P 2800 hot-carrier diode multiplier. Usable harmonic energy up to 1296 MHz been observed on a spectrum analyzer. With the circuit shown, the output was -82 dBm at 1296 MHz, a readily detectable level. A plot of output vs. frequency is shown in **table 1**.

Basically, the circuit is an untuned Colpitts crystal oscillator driving a wide-band buffer, which in turn drives the hot-carrier diode multiplier. Two pots are used to adjust the output level. R2 sets the voltage level of G2 in the oscillator. This control is set to either of two calibrated points depending on the application. For example, if weak signal testing is desired, R2 is adjusted to the point at which oscillation is barely sustained. If a strong signal is desired, R2 is set to maximum output. The output-adjust pot, R7, sets the voltage of G2 on the 40673 buffer. The pot shown gives a -40 dB change in output level. This adjustment range can be calibrated in conjunction with a known attenuator and your receiver S-meter. Another approach is to mark off a 10-dB range in 1 dB steps on R7's scale and use an external attenuator for coarse adjustments.

construction

I used double-sided copper circuit board soldered together to form a 3 x 6 x 1 1/2 inch box. An LMB or Bud aluminum box of equivalent size could be used and the circuit built on a copper

Bruce Clark, K6JYO, 1019 El Dorado Drive, Fullerton, California 92632

sub-chassis inside as shown in fig. 2. However, rf leakage may be a problem at low levels using this construction. Extra

vhf converter alignment

A word of caution about the use of the signal source for vhf front end align-

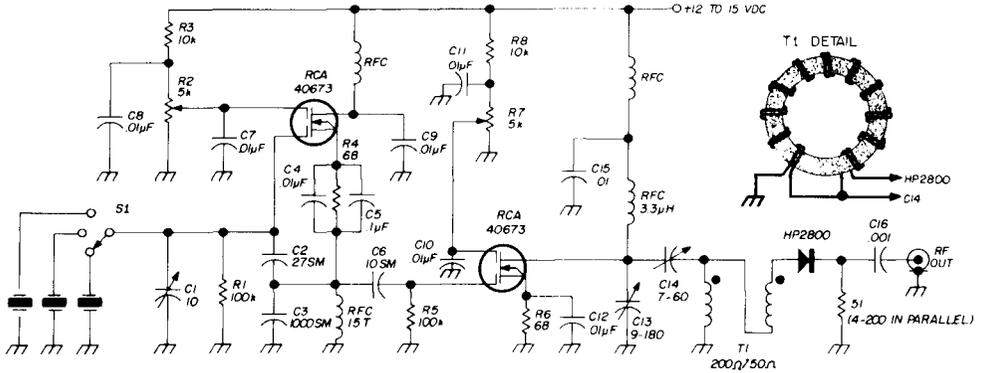


fig. 1. Schematic of the weak-signal source. T1: 7 turns no. 28 or 30 wire, bifilar-wound on no. 3E2A Ferroxcube toroid form. Rf chokes: 10 turns no. 24 or 26 on same form as T1 unless specified otherwise. C13: Arco 423. C14: Arco 404.

screws must be used to keep the box rf tight. This will minimize leakage for most applications.

A simple ac supply capable of supplying 12-15 V at 25 mA may be built in the box; or if desired, a 12-15 V battery supply may be substituted. If an ac supply is used, the line cord should be well bypassed with feedthrough capacitors to eliminate rf leakage from this source.

applications

The uses of the unit are many. With a 1- or 3.5-MHz crystal, it makes an excellent frequency standard, band-edge marker, or receiver alignment generator. With an 8-MHz crystal, it can serve as a weak-signal source for vhf front-end alignment. In its maximum power output mode, the unit becomes a signal source for neutralizing converters and high-power rf amplifiers.

Other applications include calibration of receiver S-meters and determination of receiver dynamic (agc) range. Also, you could probably replace the harmonic generator with a tuned circuit, key the buffer, and go super QRP!

table 1. Output vs frequency.

frequency (MHz)	harmonic	output level (dBm)
8	-	-2*
16	2	-3.4
32	4	-17.4
48	6	-24.4
64	8	-29.0
144	18	-44.0
216	27	-51.2
432	54	-63.2
1296	162	-82.3

*0.625 mW across 50 ohms

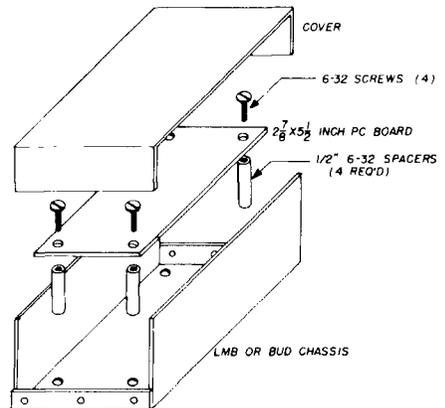


fig. 2. Alternate chassis design. An rf-tight enclosure is a must (see text).

ment: if the device under test (fig. 3) has little front-end selectivity or is badly mistuned, it may be possible to tune it up on the wrong harmonic of the signal source; e. g., a 432-MHz converter with a 28-MHz i-f should be tuned up on its 54th harmonic (assuming an 8.000-MHz

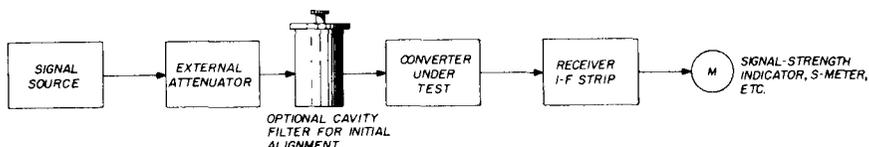


fig. 3. Setup for alignment of vhf converters.

crystal in the source). However, the 47th harmonic of 8.00 MHz is 376 MHz, which is the image frequency of the converter. Since this is a lower-order harmonic, it contains more energy than the desired one and could be the source of a lot of frustration. A similar situation exists with a 144-MHz converter using a 28-MHz i-f where the 18th harmonic is 144 MHz and the 11th harmonic is 88 MHz, which is the image. The solution in these cases is to include some selectivity between the signal source and the unit under test, at least until you're sure the converter is properly adjusted to the desired frequency. A second method is to offset the crystal frequency a few hundred Hz high using C1. The lower-order harmonic on the image frequency will then fall below the desired harmonic and can be easily identified.

fig. 4. Arrangement for neutralizing receiver or transmitter rf amplifiers. Procedures are given in the text.



neutralization of rf amplifiers

Fig. 4 shows the arrangement for neutralizing a receiver or transmitter rf amplifier. The procedure for receiver amplifier neutralization is as follows:

1. With B+ off disable the amplifier by opening the source bias resistor or

opening a filament lead.

2. With signal source at maximum output, tune in signal on receiver.
3. Peak input and output circuits, then adjust neutralizing control for a null. Repeat several times.

4. Reconnect source bias resistor of filament lead.

For transmitter power amplifiers:

1. For tube rigs, turn off B+ and screen voltage. For transistor transmitters, leave B+ on and open emitter lead.
2. Connect weak-signal source to input. Adjust to maximum signal level.
3. Connect receiver to rf output of amplifier.
4. Tune in signal source and peak amplifier input and output controls for maximum S-meter indication on receiver.
5. Adjust neutralizing capacitor for minimum signal feedthrough. Repeat several times for maximum null.

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ham radio

multimode i-f system

External refinements
for older receivers —
featuring ssb, fm,
and synchronous
a-m detection
plus a wide-range
audio compressor

Richard Factor, WA2IKL, 30 West 60th Street, New York, New York 10023

Here's an outboard i-f and audio system that can be used with older receivers to bring them up to today's standards. Most older sets have little room to spare for adding a selective filter and product detector — essential requirements for good ssb performance. In addition to normal ssb operation, the circuit described here provides:

1. An fm detector essentially immune to a-m interference.
2. An audio compressor with a wide dynamic range and slow time constant, which eliminates constant riding of the volume control during net operation and fm-channel monitoring.
3. Synchronous a-m detection.

the circuit

The multimode i-f and audio system schematic is shown in **fig. 1**. Semiconductor enthusiasts will note an assortment of rather unusual ICs in the i-f and detector circuits. One of the new Signetics phase-locked loops, the PLL 560, is used as an f-m detector and carrier generator. A Motorola MC1596 balanced-modulator IC operates as a balanced demodulator in the product detector. The audio compressor, **fig. 2**, uses a type 709 op amp with a Raysistor CK1112 as the gain-control element.

To understand how the i-f/detector works, refer to **fig. 3**, paying particular

attention to the switch positions for each mode.

single sideband reception

Sideband operation is similar to that in

reception a 50 Hz error isn't serious, but in a-m reception any error is a disaster. You have a carrier and a bfo signal. If a phase difference exists between them, their outputs may cancel, leaving no

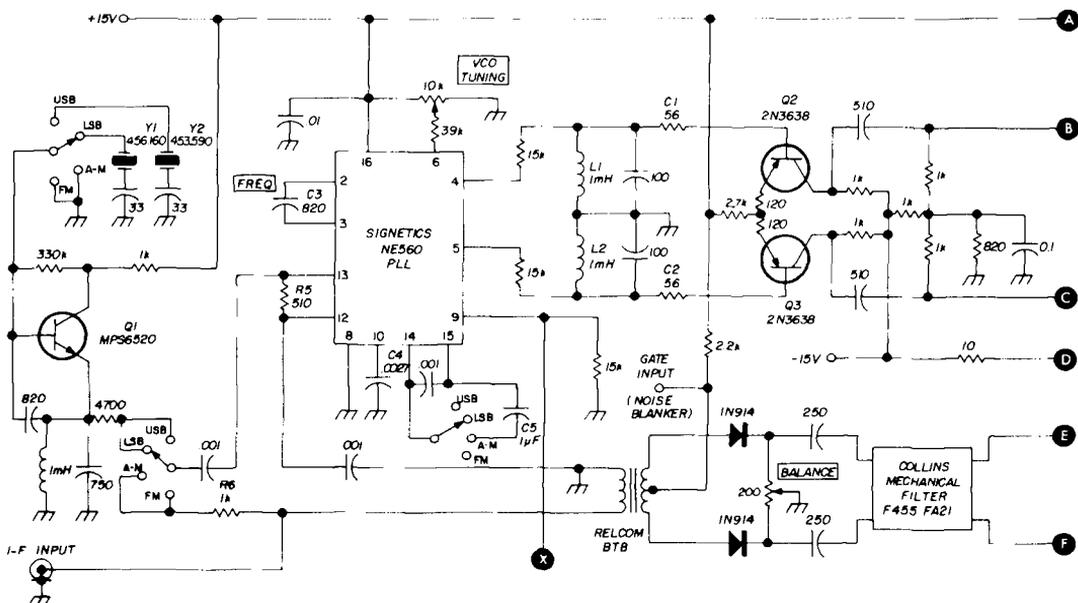


fig. 1. Schematic of the multimode i-f/audio system. Substitute devices may be used; e.g., the less-expensive PL 565 can replace the PLL 560. Also, equivalent IC's by Fairchild and Signetics are available for the balanced demodulator.

standard receivers: the bfo generates a signal equal to the (suppressed) carrier frequency of the signal you are tuning. The mechanical filter passband is above the bfo for usb; below it for lsb. The bfo output goes to the phase-locked-loop input, and the loop vco output goes to one input of the product detector. In this operation, the phase-locked loop acts as a buffer since the input frequency is equal to the output frequency, and the vco output is the only signal used. The mechanical filter output goes to the other product-detector input, and the output of the product detector is the reconstructed audio signal.

a-m reception

If you try to receive a-m with a sideband receiver, inevitably you run into the problem of precision tuning. In ssb

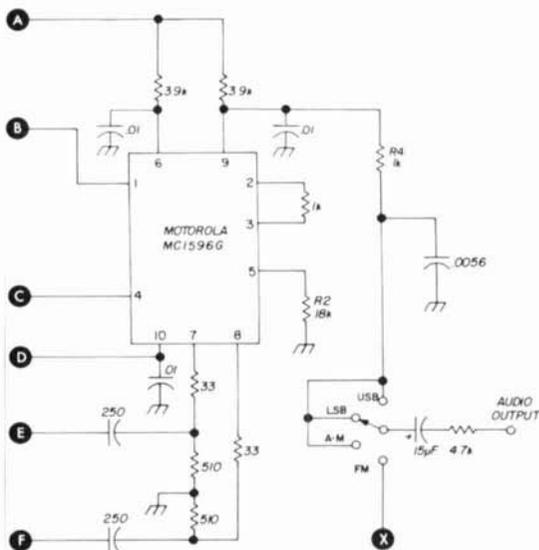
reference for demodulation. If there is a frequency error a flutter will occur as the phases change, or a beat note will occur if the phase difference is sufficient. Synchronous detection eliminates these problems.

The a-m signal is simultaneously applied to the mechanical filter input and the phase-locked-loop input. The phase-locked-loop synchronizes with the carrier of the a-m signal and provides a reference of the correct phase to demodulate the signal. Meanwhile, the signal is processed by the mechanical filter, which can be positioned anywhere with respect to the carrier frequency, thus improving selectivity.

f-m reception

The phase-locked loop synchronizes with the carrier of the incoming signal. If

the signal increases in frequency, a dc voltage produced by the loop increases the oscillator frequency. If the signal decreases in frequency, the dc voltage decreases to re-sync the oscillator. Thus,



the dc voltage is proportional to the input frequency. Producing a voltage proportional to the frequency of the input signal is called f-m detection. The allowable deviation of the f-m signal is dependent upon the receiver i-f bandwidth before the mechanical filter. This will usually be sufficient to copy downconverted two-meter signals.

compressor

The compressor consists of an operational amplifier with a variable resistor in the feedback loop. A low resistance decreases the gain. Since the "resistor" is light dependent, it can be controlled electronically. The op-amp output is rectified and applied to a long-time-constant RC network at the input to a Darlington stage. The Darlington output goes to the lamp half of the Raysistor. Thus, as the amplifier output tends to increase, the circuit gain decreases, maintaining a constant average output through a wide dynamic range.

circuit details

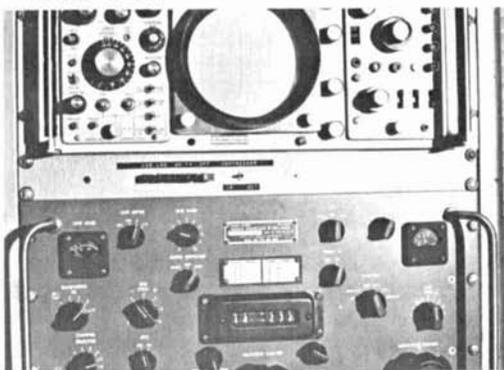
The i-f input from my receiver was about 1V p-p into 50 ohms. This was ideal for driving a 2-to-1 broadband transformer I had available. The transformer output is balanced, which makes it ideal for gating if you wish to use a i-f noise blander.

Preliminary experiments indicated that a noise blander inserted here offered little improvement over conventional limiters, probably due to the already narrow selectivity. So if you don't have such a transformer don't worry about it. Just connect the filter directly to the i-f output. The filter output is resonated by the two 250-pF capacitors and is connected differentially to the product-detector input. The two 33-ohm resistors are parasitic suppressors. R1 and R2 set the product detector gain and bias. R1 may be adjusted, depending upon the receiver i-f output. R2 should be adjusted if you wish to use a different power-supply voltage. R3 and R4 and the associated capacitors form a low-pass filter on the product-detector output to keep 455 kHz signals out of the rest of the circuit.

buffer and bias network adjustment

The assembly between the vco output and the product detector carrier input

Front view of the external multimode i-f/audio and compressor system. Note the neat arrangement of the rack-and-panel unitized packaging. Receiver below the multimode system is a Collins R-391.



named after. However, the important thing is that, if you have spent as many hours as I have trying to get those miserable FT243 crystals to oscillate, you'll be happy to have a decent circuit regardless of whom it is named after. One important note: keep the leads to the crystals short or this circuit won't work either.

construction

I built the final unit as shown in the photos. The bfo and input circuits are on one side of the filter; the product detector and audio circuits are on the other. Before building the final unit, I breadboarded the circuits. All the components had long leads, but both circuits seemed to perform equally well. However, leads

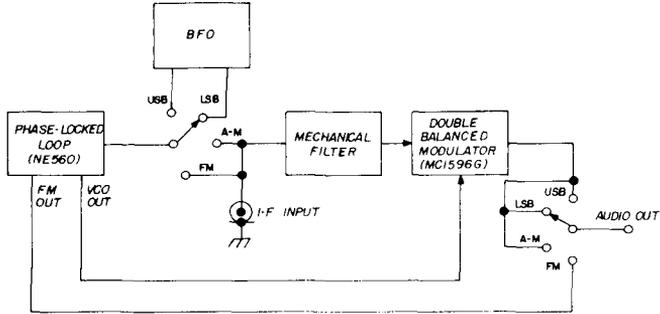


fig. 3. System block diagram.

compressor design

The Raytheon CK1112 Raysistor may be difficult to obtain. A Raysistor can be built for about a dollar, using a cadmium sulfide photocell and a low-current pilot light. R7 is determined by connecting it in series with the lamp and the power supply. Enough current should flow in the lamp to give a photocell resistance of 1 – 2k. Measure the lamp voltage under normal operation. R8 should be connected in series with R7 to the lamp when you don't want compression in this way, compression can be switched in and out without changing the circuit gain and without introducing transients in the audio circuit. R9 sets the minimum gain of the op amp with the photocell fully conducting. R10 sets the gain with the photocell off. The ratio of these resistors is approximately equal to the amount of compression available. The values I have used give a range of about 55 dB, which is somewhat extravagant since an audio signal-to-noise ratio of 55 dB is seldom encountered in ham work. Vary these resistors to suit your taste. They are relatively independent of the type of photocell you use.

should be short to keep rf radiation to a minimum. I used many bypass capacitors and parasitic suppressors. If you want to leave them out, do so at your peril. The inherently balanced circuitry probably contributed as much to stable and reliable operation as did the wiring technique.

parts availability

The PLL 560, which at this writing is fairly expensive, can be replaced by a PLL 565, which isn't. The balanced demodulator is manufactured by Motorola, Fairchild, and Signetics. The Collins mechanical filter can probably be replaced with a Japanese unit that I've seen advertised for much less money. The BT8 transformer and CK1112 Raysistor have already been discussed. Everything else is quite inexpensive. The money you save on parts might well pay for one of those old surplus receivers, which can be resurrected with the multimode i-f system described here.

reference

1. Jim Kyle, K5JKX, "The Phase-Locked Loop Comes of Age," 73, October, 1970, page 42.

ham radio

simple transconductance tester for field-effect transistors

A versatile,
low-cost
test circuit
for checking
the performance
of field-effect
transistors

Robert S. Stein, W6NBI, 1849 Middleton Avenue, Los Altos, California 94022

At the last West Coast VHF Conference my favorite two-meter fet converter's noise figure was checked and found wanting. Since this converter¹ had previously been measured at better than 2 dB it was apparent that it needed some work. The signal generator, sweep generator and noise generator were broken out in an effort to restore the beast to its original operating condition. After many fruitless hours of alignment and checking the converter was only slightly improved and was still far below what it should have been.

Although I had replaced the fet in the first r-f stage I had not checked the other fets, but assumed that they were good since the converter was working. By accident (or for reasons I don't remember) I removed the second r-f amplifier fet from its socket. There was virtually no difference in received signals with or without the fet! The transistor was dead. With a new fet in the socket it took all of 15 minutes to realign the converter, restore the bandwidth to 4 MHz, and verify that the noise figure was once again better than 2dB.

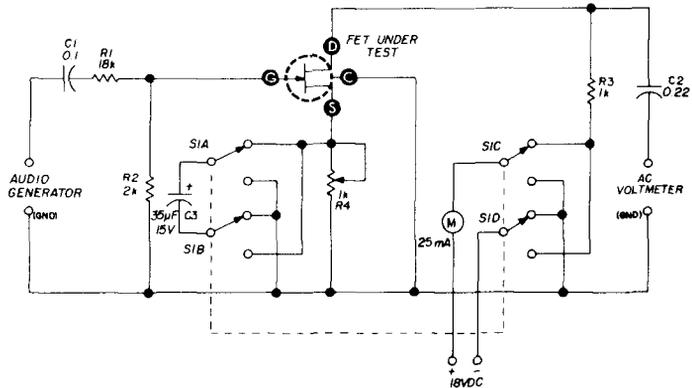
A little analysis showed what was happening. The defective stage was a neutralized common-source amplifier. With a dead transistor the signal at the gate lead was coupled across the neutralizing inductance to the drain tank circuit and the mixer, less 10 dB of amplification.

Everyone knows the first step in

troubleshooting is to check the suspect tube or transistor. However, this requires a suitable tester, which I did not have. I have one now, though, that uses an external audio oscillator and ac voltmeter or oscilloscope (see fig. 1). Cost, even with all new components, is minimal.

calibrated oscilloscope connected across the output terminals indicates the output voltage developed across the 1k drain load, R3. The forward transconductance of the transistor under test, in micromhos, is equal to 10,000 times the output voltage. Thus, if the voltmeter

fig. 1. Circuit of the fet transconductance tester. Switch S1 is a 4-pole, double-throw, non-shorting rotary.



circuit

A 1-volt, 1000-Hz audio signal is applied to the input of the fet tester. R1 and R2 form a 10:1 voltage divider that reduces the signal at the gate of the fet under test to 100 millivolts; virtually no gate current will flow under zero-bias conditions. An external ac voltmeter or

*The explanation of this relationship is as follows. The forward transconductance, g_{fs} , of the device under test may be expressed in mhos as

$$g_{fs} = \frac{i_d}{e_g}$$

where i_d is the a-c component of the drain current (in amperes) and e_g is the a-c gate voltage. From Ohm's law,

$$i_d = \frac{e_o}{R_d}$$

where e_o is the a-c output voltage and R_d is the drain load resistance (designated R3 in fig. 1). By substitution,

$$g_{fs} = \frac{e_o}{e_g R_d}$$

If $e_g = 0.1$ volt and $R_d = 1000$ ohms, the conditions under which this circuit operates, then

$$g_{fs} = \frac{e_o}{100} \text{ (mhos) or } 10,000 e_o \text{ (micromhos)}$$

across the output terminals reads 0.4 volt, the transconductance of the device under test is 4000 micromhos.*

Potentiometer R4 is used to set the source bias and hence, the drain current of the fet. There is a wide variation in drain currents of individual transistors of the same type. The manufacturer usually specifies a normal operating drain current so it is helpful to monitor the drain current and set it to the desired value with R4. The milliammeter may be built into the tester or connected in series externally with the power supply.

Switch S1 reverses power-supply polarity so the power supply connections do not have to be reversed when changing from n- to p-channel devices. This switch also reverses the polarized source-bypass capacitor, C3. This capacitor is needed to prevent degeneration across R4 which would reduce the transconductance reading. If S1 is set to the wrong position no damage will occur to the transistor; the output reading will be zero, or very low. Reversing the switch position will result

in a substantially higher reading if the transistor is good. Thus, the tester will also indicate whether the fet is a p- or n-channel type. In addition to testing junction fets, the fet tester will also check *single-gate* depletion-type mosfets.

construction

The fet tester may be built in, or on, virtually anything. I used an old plastic box; this permitted me to use ordinary 6-32 screws as input, output and power supply terminals without additional insulation. Lead length and physical layout are not at all critical; the tester can truly be built from junk-box parts.

Since there is absolutely no standard basing configuration for the many types of fets on the market the test socket may be wired according to personal preference. However, be sure to designate on the tester which pin is which so that you can insert the fet properly.

external requirements

Although the voltage of the external power supply is not critical 18 volts has been specified for two reasons: 18 volts is high enough to keep the drain potential above the knee of the E_D - I_D curve if the device under test draws sufficient drain current to cause an appreciable drop across R_3 ; 18 volts is below the normal breakdown voltages specified for most transistors.

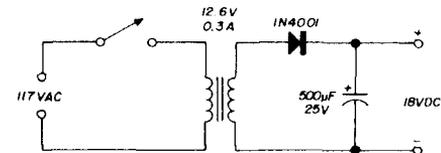


fig. 2. Suggested power supply for the fet tester.

The circuit for a suitable ac power supply is shown in fig. 2. This could be incorporated into the tester if desired. However, it is probably easier and cheaper to use two 9-volt transistor-radio bat-

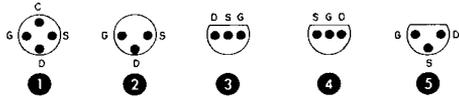
teries. Since the current drain is intermittent and rarely exceeds 15 mA they should last their entire shelf life.

The audio oscillator must supply a reasonably good sine wave at 1 volt rms

table 1. Characteristics of popular field-effect transistors.

type	channel	base diagram	trans-conductance (μmho)*	I_{DSS} (mA)
2N3823	N	1	3500-6500	4-20
2N4360	P	2	2000-8000	3-30
2N4416	N	1	4500-7500	5-15
2N5397	N	1	6000-10,000	10-30
2N5398	N	1	5500-10,000	5-40
E300	N	2	4500-9000	6-30
MPF102	N	3	2000-7500	2-20
MPF103	N	3	1000-5000	1-5
MPF104/2N5458	N	3	1500-5500	2-9
MPF105/2N5459	N	3	2000-6000	4-16
MPF106/2N5485	N	3	2500-6000	4-10
MPF107/2N5486	N	3	4000-8000	8-20
MPF108	N	3	2000-7500	0.5-24
MPF109	N	3	800-6000	0.5-24
TIS34/2N5248	N	4	3500-6500	4-20
TIS88/2N5245	N	5	4500-7500	5-15
TIXM12	P	2	5000-20,000	5-25
UC734	N	1	3500-6500	4-20

*Transconductance at $V_{GS} = 0$.



into a high-impedance load. The frequency of 1000 Hz was selected because many manufacturers specify forward transconductance at that frequency. Actually, any audio frequency will serve, provided the capacitors in the circuit are increased proportionately if a lower frequency is used. For example, if you decide to use a 60-Hz source, the values of C1, C2 and C3 must be increased roughly by the ratio of the frequencies, 1000/60, or approximately 16 times.

operation

Operating the fet tester is very simple. Connect the audio oscillator to the input terminals and set the audio voltage to exactly 1 volt. Connect the ac voltmeter (or oscilloscope) to the output terminals; if an external power supply is being used

connect it to the dc supply terminals. Set switch S1 to the position which corresponds to the fet to be tested — n or p channel.

Put the fet in the socket, being careful to match its leads to the socket pin designations. It should be noted that junction fets are symmetrical devices so drain and source leads can be interchanged with no difference in performance. The gate lead, however, must be in the proper socket hole.

To check a depletion-type mosfet be sure to keep all of its leads shorted together with a strand of wire before it is inserted or removed from the socket. Also, be certain that the bulk or substrate lead, which is generally common to the case, is properly connected.

Adjust R4 for the desired drain current and read the output voltage. Multiply by 10,000 and you have the forward transconductance in micromhos. If the output voltage is abnormally low, reverse the position of S1. If you still do not get a normal reading on the ac voltmeter, and the transistor is properly connected, the transistor is defective. Conversely, switch S1 may be used to determine whether the transistor is a p- or n-channel type. The switch position which results in the lower dc drain current indicates the type.

Table 1 lists some of the more common fets with their transconductance range, zero-bias drain current (I_{DSS}) and biasing configuration. Note that the transconductance is specified at zero gate bias (V_{GS}) which results in I_{DSS} . The higher the drain current, the higher the transconductance.

Although the fet tester will probably be used infrequently, as is true for any transistor or tube checker, the small amount of time, effort and money required to build it can pay off handsomely (just reread the first three paragraphs of this article).

reference

1. William I. Orr, W6SAI, "Radio Handbook," 18th edition, Editors and Engineers, New Augusta, Indiana, pages 624-629.

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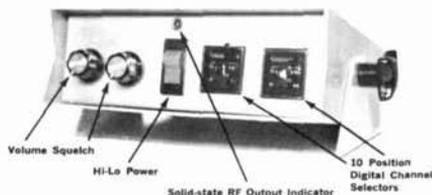
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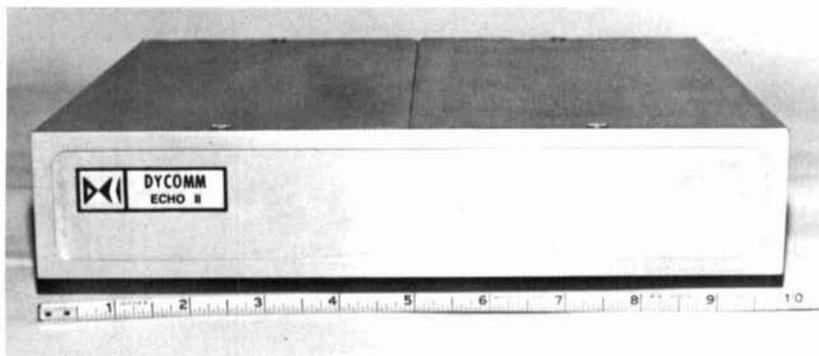


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with drifting RTTY
signals and is
particularly useful
with drift-prone
receivers

The automatic frequency-control circuit described here is the result of trying to copy the Weather Bureau's RTTY station on 14.395 MHz with a not-so-stable communications receiver. After trying to stabilize the receiver so my ST-5 demodulator¹ would copy unattended for a reasonable length of time it began to look as though an afc system might be easier. The circuit in **fig. 1** is simple and uses low-cost integrated-circuit operational amplifiers and surplus 44-mH toroids.

circuit operation

Since it's necessary to present a 2975 Hz tone to the 2975 tuned circuit in the demodulator, 2975 Hz looked like a good standard for frequency control. In this circuit U1 amplifies the 2975 Hz signal that is intermittently present during reception. A high input impedance prevents loading the demodulator tuned circuit.

The IC op amp is set for a gain of about 2.7; the output is coupled to a pair of tuned circuits. One of the circuits is tuned to about 150 Hz above 2975; the other is tuned about 150 Hz below. The rectified dc output voltages are opposite and cancel when the frequency is about midway (2975 Hz).

As the input frequency goes up the voltage goes negative; as the frequency goes down the circuit provides a more positive output. However, the voltage swing is not large enough for control purposes, so another op amp must be used as a dc amplifier. These amplifiers provide an output that swings from positive to negative with respect to ground, duplicating the polarity of the discriminator output. The output voltage from U2 is

E. R. Lamprecht, W5NPD, Route 3, Box 207, Victoria, Texas 77901

fed to a varactor or tuning diode installed in the receiver's tuning oscillator (fig. 2).

When the frequency drifts so the RTTY tone goes up, the discriminator output goes more negative; tuning diode

operating point properly; the bias control (R2) adjusts bias through the inverting input of U2. Because of the high resistance in the non-inverting input (pin 3) the necessary bias is slightly negative.

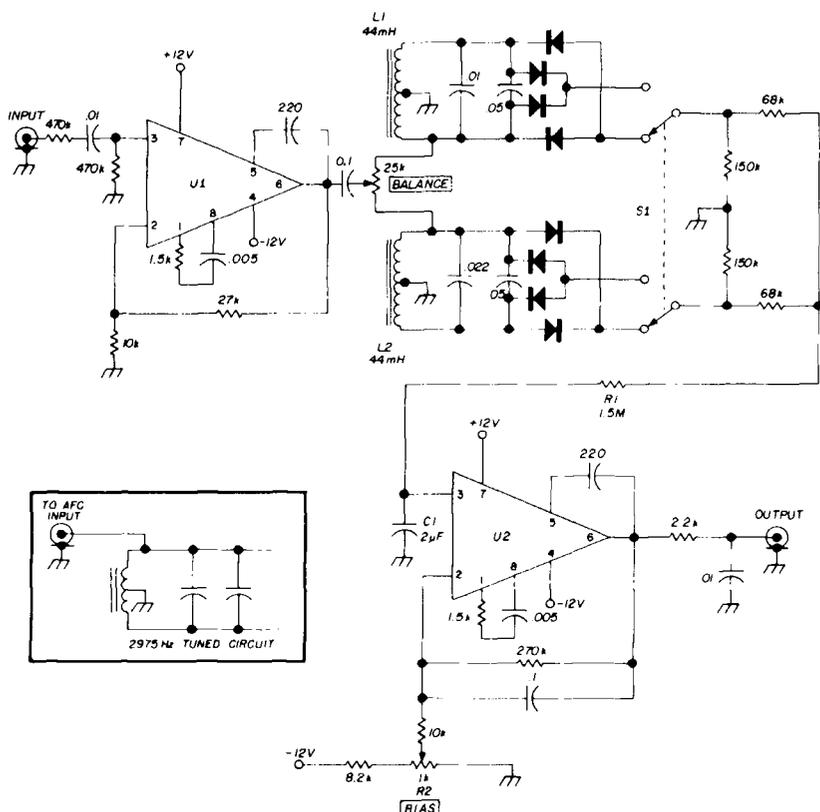


fig. 1. Circuit for the RTTY afc unit. Discriminator diodes are germanium types such as 1N34A. Integrated circuits U1 and U2 are 709 types: Motorola MC1709CG, TI SN72709L, Fairchild uL709C, etc. Inset shows 2975-Hz signal pickup in RTTY demodulator.

capacitance decreases, increasing the oscillator frequency to bring the audio tone back to 2975 Hz.

In most RTTY signals 2975 Hz is used as the mark tone. Therefore, it is present for a larger percentage of time than the space signal. Since the tone is constantly on and off a simple RC filter (R1, C1) presents a long time constant to the pulsating dc and smooths the output to prevent warble of the receiver audio.

The varactor must be biased to set its

Two units were tried; one required -0.4 V, the other, -0.35 V.

initial setup

After a thorough wiring check connect the unit to the receiver and RTTY demodulator. (Power from the ST-5 plus and minus power supply may be used since total current drain is only 5 mA. If the unit is used with another demodulator or use any well filtered power supply, or batteries.)

The afc circuit is connected to the communications receiver through capacitor C2 (fig. 2); connect it to the cathode of the oscillator tube (or emitter of a transistor oscillator). Connections to high-impedance points in the oscillator circuit may result in large changes in dial

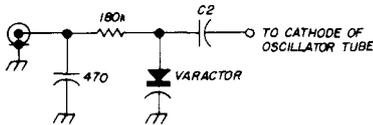


fig. 2. Varactor tuning circuit connects to the cathode of the oscillator tube. The varactor is not critical; it may be a silicon rectifier such as the 1N4383 or a small 20-pF voltage-variable diode. See text for selecting proper value for C2.

calibration. If this is necessary a very small value should be used at C2. Capacitance should be slightly less than that which causes a noticeable audio warble or chirp when a RTTY signal is received. A 5- or 10-pF capacitor is a good starting point.

adjustment

For proper adjustment, connect a vtvm across the output jack and make the following adjustments:

1. Disconnect the input cable from the demodulator.
2. Adjust the *bias* control to -5 volts output.
3. Connect the demodulator to an accurate 2975-Hz tone.
4. Adjust the *balance* control to bring the output back to -5 volts.
5. Remove the 2975-Hz tone and connect the demodulator to the receiver.

When a RTTY signal is properly tuned the vtvm will read -5 volts. This reading will go up or down as you tune across the signal. The 10-volt scale makes a fine tuning indicator with -5 volts as zero

center. If you tune slowly the audio RTTY tones will remain nearly the same.

Depending on the relative positions of the bfo and the receiver oscillator it may be necessary to reverse S1. If the polarity is wrong for your receiver the afc unit will *prevent* you from tuning in a RTTY signal!

The voltage at either end of the 2975-Hz coil in the ST-5 demodulator is on the order of 12 volts peak-to-peak. When using another type of RTTY demodulator the input signal to U1 should be approximately at this level. This may be accomplished by lowering the resistance between pin 3, U1, and ground if the signal is too large. If the signal is too low the gain of the first op amp may be increased by increasing the value of the 27k feedback resistor between pins 6 and 2 of U1.

This afc unit has proven very useful in my station. It allows the use of an inexpensive receiver to monitor a RTTY station for long periods of time without retuning to compensate for receiver or transmitter drift.

reference

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

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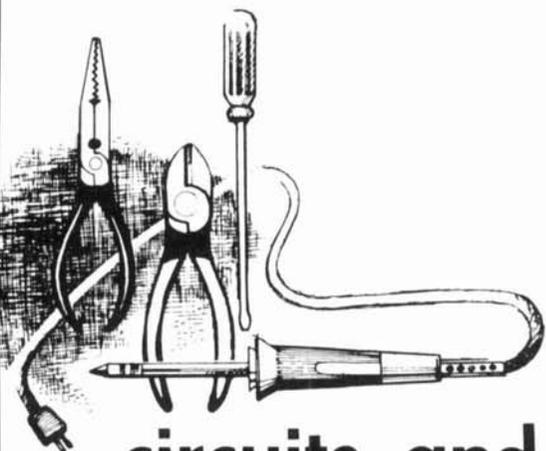
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circuits and techniques ed noll, W3FQJ

phase-locked loops

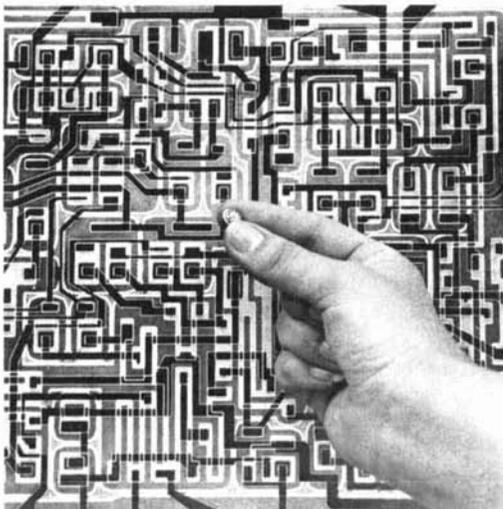
Do you wish that your local oscillator would hold precisely on frequency after you have tuned in an a-m, fm or fsk signal? How would you like to automatically track an incoming signal that drifts in frequency? How would you like to demodulate that signal even though it is plastered with noise? For an affirmative answer to any of these questions you must enter the realm of the phase-locked loop. A fine discussion of the basic theory of this circuit was presented recently by VE5FP.¹

Although the phase-locked loop concept has been around since the early 1930s its high complexity has limited its use to specialized applications in expensive military and avionics equipment. For an idea of the complexity of this circuit consider an amateur radio version of the phase-locked loop described by W2CRR and W0AHN² that used a total of 16 vacuum-tube stages or VE5FP's solid-state phase-locked oscillator that uses 7 transistors plus a large quantity of re-

sistors, capacitors and inductors. It's no wonder that this versatile circuit has seen little application in amateur radio equipment.

The integrated-circuit versions of the phase-lock loop are as complex as their discrete component counterparts. The Signetics NE560 for example, the first phase-locked loop IC, contains no less than 25 transistors, 7 diodes and 27 resistors. With this device it is possible to build high performance fm detectors, RTTY demodulators, signal-tracking filters, stable local oscillators, frequency synthesizers and frequency multipliers as well as more complex systems. Additional components included in its sister unit, the Signetics NE561B, provide capability for operation as a frequency-selective (coherent) a-m detector. These monolithic phase-locked loops have a frequency range from 1 hertz to 15 MHz without the need for tuned circuits.

Signetics integrated-circuit IC is dot at the center of the package held here in the fingers. Background is greatly magnified photograph of the circuit as it would appear through a microscope.



applications

There are several applications for phase-locked loop ICs in amateur communications receivers. They can be used as small efficient synchronous a-m detectors with excellent linearity and noise

fm demodulator, the phase-locked loop IC may be your answer; it is an efficient demodulator that will accommodate any i-f frequency up to 15 MHz. (A multimode i-f system for fm, a-m and ssb which is designed around the Signetics NE560 is

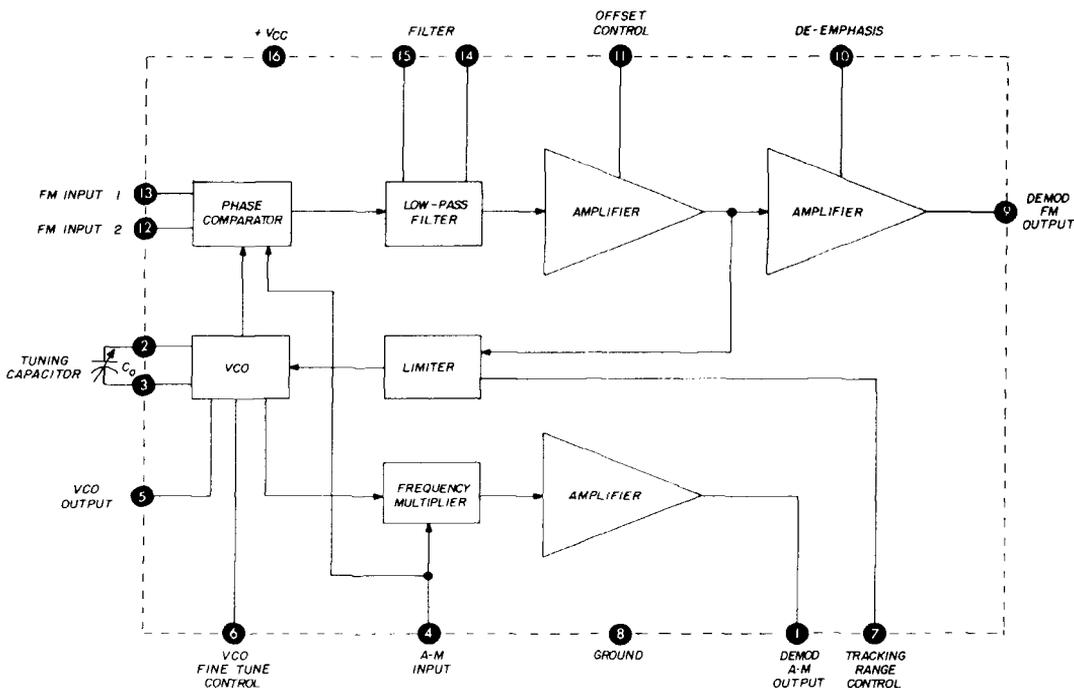


fig. 1. Block diagram of the Signetics NE561B phase-locked loop integrated circuit.

immunity. Can they make vhf-uhf a-m DXing a more realistic endeavor? How about tuning in and holding a-m signals on bands crowded with other signals? I'll soon be checking one out on 160 meters.

For fm the phase-locked loop IC may be used in compact i-f, limiter and demodulation systems. The IC's wide frequency range and no-tuning characteristic are especially attractive in receiver designs that use more than one i-f frequency.

How about a direct-conversion fm receiver? For 10-meter operation this is probably possible today using off-the-shelf phase-locked loop ICs. If you already have a high-quality communications receiver to which you would like to add an

described by WA2IKL on page 39 of this issue).

Application of the phase-locked loop concept will also provide a stable vfo or frequency synthesizer for amateur fm operation. The phase-locked loop can also be used to advantage in an a-m receiver that will hold precisely on a net frequency and still follow those stations that just can't seem to find the right spot.

In addition, the phase-locked loop IC operates well as a frequency multiplier or a frequency divider. With a stable crystal reference oscillator or vfo, the vco in the IC can be operated on a harmonic or sub-harmonic of the reference frequency. These capabilities encourage the design of

versatile frequency calibrators and high-stability multiband vfos.

phase-locked loop ic

A block diagram of the Signetics NE561B phase-locked loop IC is shown in fig. 1. An incoming fm signal is applied to the phase comparator through pins 12 and 13. A reference signal from the voltage-controlled oscillator is applied internally. The vco frequency is adjusted externally with a variable capacitor between pins 2 and 3, or with a dc control voltage connected to pin 6. The vco output is available at pin 5.

The output of the phase comparator is applied to a low-pass filter. The filter characteristics are controlled with an external network connected between pins 14 and 15. A two-stage amplifier follows the low-pass filter. The de-emphasis characteristic is set with a capacitor from pin 10 to ground. The demodulated fm output is available at pin 9.

The dc error voltage at the output of the first amplifier is applied to the limiter. This filtered error voltage is applied to the vco, causing it to phase lock to the incoming signal. When the incoming fm signal deviates in frequency with modulation the error voltage developed at the output of the phase comparator corresponds to the demodulated output.

When a phase-locked loop locks on an fsk signal the error voltage from the phase comparator is in discrete voltage steps that correspond to mark and space, or the digital 1 and 0.

A-m demodulation (coherent detection) circuit operation uses all the fm demodulation circuits *plus* a multiplier which functions as a mixing-type a-m demodulator. The incoming a-m signal is applied to the mixer input at pin 4. The IC locks on the a-m carrier frequency; in fact, the output of the vco is the same frequency as the carrier but without modulation.

The vco signal is also applied to the multiplier. A low-pass filter at the output of the multiplier cancels the rf carrier and

sideband components and produces a difference signal corresponding to the a-m modulation. This system of demodulation is referred to as phase-lock a-m detection. It is much less subject to noise than conventional a-m detectors.

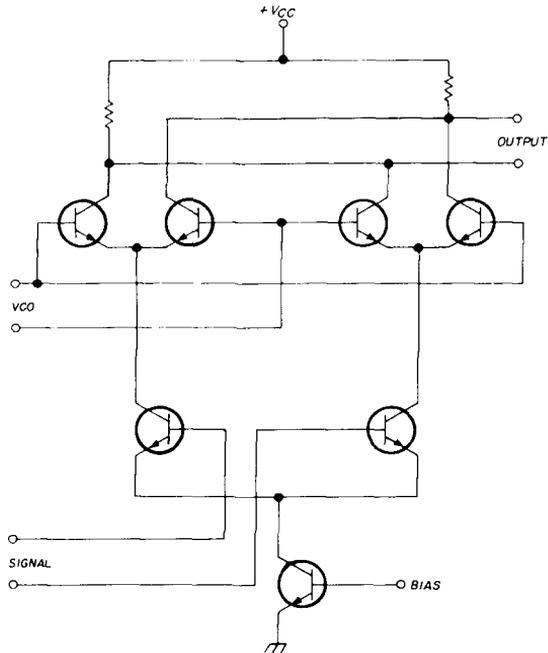


fig. 2. Basic phase comparator and multiplier circuits use differential transistor arrangement.

phase comparator

A simplified phase detector that is very similar to the one used in the NE561B is shown in fig. 2. This is the same differential amplifier I've described in previous *circuits and techniques*. Connect two differential amplifiers in a balanced arrangement and you come up with a balanced modulator, balanced demodulator or balanced mixer. The vco output is connected to the bases of the differential pairs; the signal is applied base-to-base of the emitter input transistors.

When the vco and input voltage are phase locked to the same frequency the output voltage is zero. An error voltage develops when the signal drifts off. In the

case of fm demodulation the recovered error voltage is actually the demodulated fm wave.

The a-m demodulator uses the same basic balanced differential arrangement as the phase comparator. The vco output is

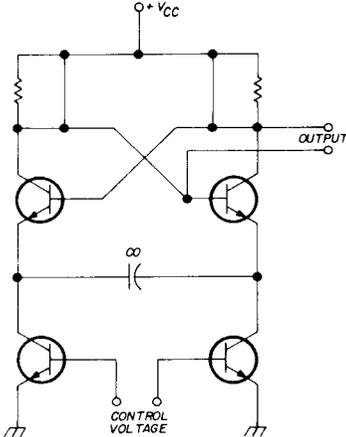


fig. 3. Voltage-controlled oscillator is a multivibrator. Basic frequency is controlled by capacitor connected between the emitters; fine tuning is provided by voltage that controls emitter current.

applied to the bases of the differential pairs; the rf a-m signal is introduced through the insert transistors in the emitter circuit. The phase comparator is also used in the a-m demodulation system to phase-lock the vco to the carrier frequency. The difference frequency out of the differential multiplier circuit (fig. 2) corresponds to the frequency separation between the sidebands and carrier of the a-m signal, hence the circuit reproduces the original audio modulation.

VCO

The voltage-controlled oscillator is an emitter-coupled multivibrator similar to the circuit shown in fig. 3. The external timing or tuning capacitor is connected between the emitters of the multivibrator transistors. At any instant of time one of the transistors is turned on and the other is off. The timing capacitor is alternately

charged and discharged by the voltage-controlled current source in the emitter circuit. The control voltage can be in the form of a dc error voltage from the phase comparator through the limiter, or an external control voltage may be introduced.

practical circuits

The circuit in fig. 4 shows how the Signetics NE561B may be used as an fm detector. The fm input signal is connected to pin 12 and 13; audio output appears across the 15k load resistor connected to pin 9. The capacitor between pin 10 and ground establishes the proper de-emphasis.

The capacitor between pins 2 and 3 determines the frequency of the voltage-controlled oscillator. Typical capacitor values for intermediate frequencies of 4.5 and 10.7 MHz are given in fig. 4. For fine tuning a small capacitor may be placed in parallel with C_o (C_x in fig. 4) or a small variable voltage may be applied to pin 6. This can be in the form of a potentiometer connected across the power sup-

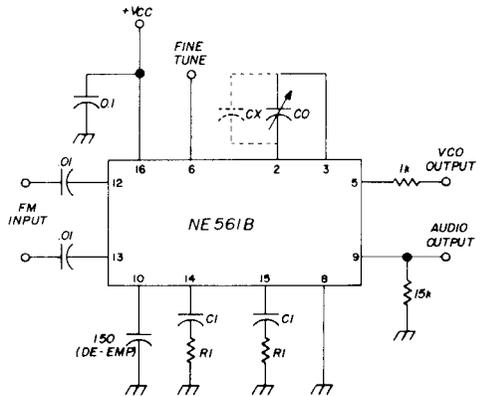


fig. 4. Use of the phase-locked loop IC as an fm detector.

ply. The low-pass loop filter components are connected between pins 14 and 15. Component values, which depend on the i-f frequency, are shown.

The frequency range over which the vco will track the signal frequency can be

altered by applying appropriate dc control voltages to pin 7 from an external and adjustable supply voltage source. In some specialized application it may be necessary to offset an internal dc com-

synchronous demodulation is established by an external 90° RC phase-shift network. These components, $R_A C_A$ and $R_B C_B$ in fig. 5, must satisfy the time-constant formula

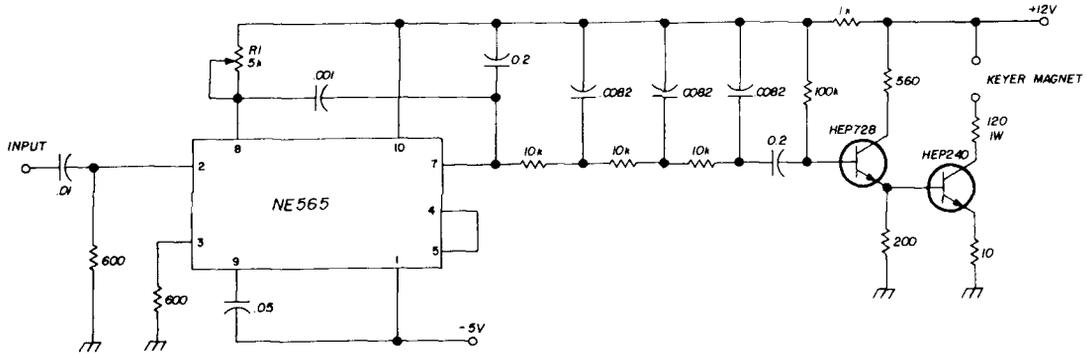


fig. 6. Phase-locked RTTY demodulator requires no bandpass filters. R_1 is adjusted so internal vco frequency is at same frequency as input.

ponent. This can be done with an external voltage source applied to pin 11.

The same IC is setup for synchronous a-m detection in fig. 5. Note that the vco, phase discriminator and low-pass filter stages are active as they were for fm demodulation. However, the multiplier circuit is also necessary for synchronous a-m detection.

In the a-m detection process the phase-lock loop is locked to the signal carrier frequency and the vco output serves as the local oscillator signal. The appropriate quadrature relationship for

$$R_A C_A = R_B C_B = \frac{1}{2\pi f_0}$$

Where f_0 is the operating frequency. The values in fig. 5 were selected for the a-m broadcast band (1.5 MHz). In this circuit the 250-pF capacitor between pins 2 and 3 tunes the IC across the broadcast band; the low-pass filter components are suitable for broadcast-band operation.

A less complex integrated-circuit phase-locked loop such as the Signetics NE565 can be operated as an RTTY demodulator without the use of bandpass filters. This IC consists of a phase detector, amplifier and voltage-controlled oscillator. Range extends between a fraction of a cycle to 500 kHz.

In the fsk demodulator circuit in fig. 6 the incoming frequency-shift signal moves rapidly between the mark and space frequencies. As it does the phase-lock loop locks on to the input signal, moving from one input frequency to the other, with a corresponding dc voltage shift at the output. The simple RC filter across the output is designed to remove frequency components between the maximum keying rate and twice the maximum input frequency. The filter components in fig. 6 were chosen for amateur opera-

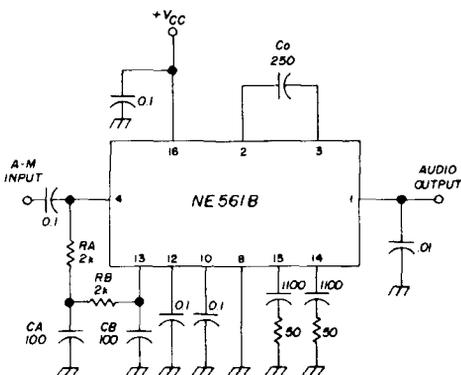


fig. 5. Synchronous a-m detector circuit. Component values shown here were selected for broadcast band (1.5 MHz).

tion (100 wpm maximum) with a 455-kHz i-f strip.

multi-ic loops

An integrated-circuit phase-locked loop does not have to be confined to a

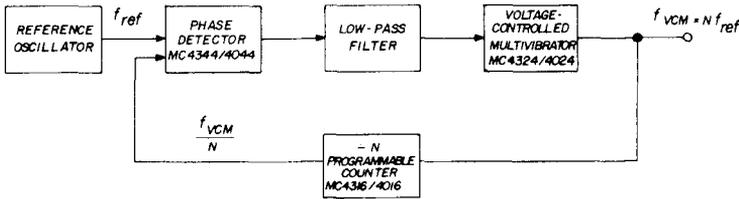


fig. 7. Frequency synthesizer uses programmable divide-by-N counter within the phase-locked loop. Typical Motorola ICs for this circuit are shown.

single IC. There are a variety of special-purpose ICs that can be combined into phase-lock systems and tailored for specific applications. For example phase-detector ICs such as the Motorola MC4344/4044 and voltage-controlled multivibrators such as the Motorola MC4324/4024 can be combined with a low-pass filter to form a simple phase-locked loop.

A system of separate integrated circuits is especially attractive for building complex circuits such as a frequency synthesizer. A typical arrangement is shown in fig. 7. With a programmable counter in the loop the system can be programmed to provide practically any output frequencies. The output signal is phase locked to a stable reference oscillator so output stability is essentially that of a crystal oscillator.

In the circuit of fig. 7 the reference oscillator signal is compared to the signal from the programmable counter. The input to the programmable counter comes from a vco which is controlled by the error voltage from the phase detector. With a 1-MHz reference oscillator and a divide-by-2 counter, the output signal is 2 MHz. With a divide-by-3 counter the output is 3 MHz; divide-by-10 counter, 10-MHz output, etc. By placing a divide-by-N counter (where N is any number) in the loop you can build a frequency synthesizer which will provide any desired output frequency.³

army loop antenna — revisited

A simple method of tuning the ends of a small resonant-loop antenna has been evolved by James E. Taylor.^{1,2} This technique, shown in fig. 8, eliminates lossy

loading-coil arrangements. Maximum horizontal length for operation on 80 meters is 20 to 25 feet. Although Taylor used RG-8/U cable for his antenna any large diameter conductor is satisfactory.

The capacitive element in fig. 8 consists of 300-ohm twin-lead. Note that the ends of the resonant loop connect to opposite conductors of the twin-lead. The loop is resonated by clipping even amounts off each end of the twin-lead. (Shortening the twin-lead lowers its capacitance, raising the frequency of the resonant loop.) The large capacitor across the feedline provides proper matching.

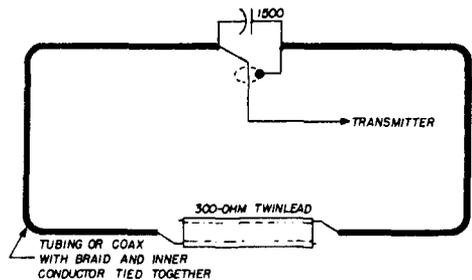


fig. 8. Balanced Taylor-loop antenna.

linear transistor amplifier

Despite the popularity of high-frequency ssb transmission there have been few bipolar transistors designed specifically for linear operation at higher power levels; most of the rf power transistors

has been designed for class-C operation. However, the new RCA 2N6093 is designed specifically for class-AB linear operation. A single 2N6093 can provide 75 watts PEP output at 30 MHz; a push-pull amplifier with two devices is capable of 150 watts PEP from 2 through

at the required dc operating levels. The device uses special subdividing of the emitter and an appropriate resistive ballast. This added resistance improves stabilization and permits low distortion operation.

Included within the transistor package

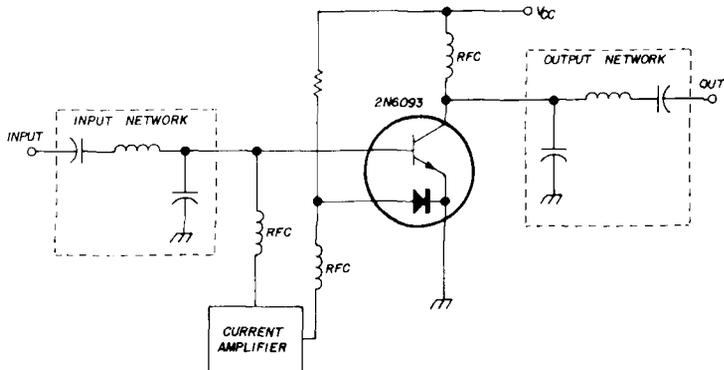


fig. 9. Basic rf linear amplifier circuit for new high-power linear rf transistor.

30 MHz.

To provide operation in class B or AB the bipolar transistor must be slightly forward biased. Unfortunately, this biasing increases the possibility of destroying the transistor because of secondary breakdown. However, the new 2N6093 transistor can be operated safely

is a temperature-sensing diode for bias compensation and run-away protection. This diode insures that the forward bias varies with temperature in the same manner as the base-emitter voltage of the transistor. An external current amplifier is required to build the diode sensing signal up to a usable level.

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*Signetics Applications memos are available from Signetics Corporation, 811 East Arques Avenue, Sunnyvale, California 94086. Motorola Applications Notes are available from Motorola Semiconductor Products, Technical Information Center, Box 20912, Phoenix, Arizona 85036.

ham radio



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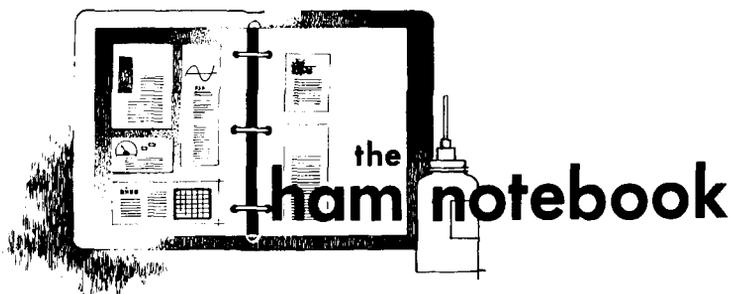
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relay activator

Occasionally, ssb exciter or transceiver relay contacts give trouble when they turn on a relay in a linear amplifier. This is part of the vox or push-to-talk system; any hang-up can be very irritating.

Some older ideas like placing an 0.5 μF capacitor in series with possibly 470 ohms, across the relay line between the exciter and the amplifier, may help. However, the cost of doing the job with a transistor is small, leaving the relay contacts with little current to handle.

If your amplifier is similar to the Henry 2K, which provides 14 to 18 volts to its relay, and requires less than 300 mA to activate it, this method will work.

Fig. 1 shows the simple circuit. The pnp transistor can be replaced with an npn if the linear provides negative instead of positive voltage to its relay phono jack. Some problems were encountered in locating a suitable transistor that would operate by shorting its base, through a resistor, to ground, in order to activate the amplifier relay, without tending to have the collector current creep toward a destructive value. However, the little 2N4918 30-watt pnp from Motorola (\$1.65) does the job very well. It has a hole permitting it to be fastened to the inside of the minibox as a heat sink — but does not seem to get warm. Since the collector is grounded no insulation is

needed between the 2N4918 and the box. This device is rated at some 40 volts; for other voltages, see adjacent type numbers (2N919, 60 volts; 2N4920, 80 volts).

The addition of a 1N2070 diode, with 400 volts inverse breakdown rating, provides protection from inductive surges from the relay coil. It was not installed initially; no problems were encountered without it. Presumably, some handy diode will be available to use as a substitute, if desired.

The base resistor worked with up to 5.6k ohms but, above that, the amplifier relay did not get enough current to pull in. Values as low as 1.5k ohms performed equally well but with slightly higher base current to be handled by the exciter relay contacts. There was no sign of creeping collector current. Using 4.2k ohms, the

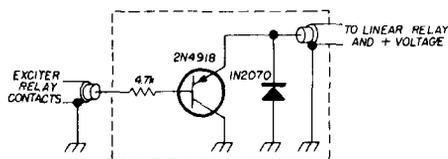


fig. 1. Relay activator operates linear amplifier relay with little current on exciter relay contacts.

transistor handled 300 mA for the amplifier relay, and required only 8 mA on the contacts of the exciter relay.

Much higher current than 300 mA probably can be handled by the 2N4918,

in which case the base resistor can be increased in order to limit the base current which will have to be handled by the exciter relay contacts. Similarly, some Henry 2K relays require only 250 mA; any relay coil requiring less than 300 mA will require a smaller base resistor for satisfactory operation.

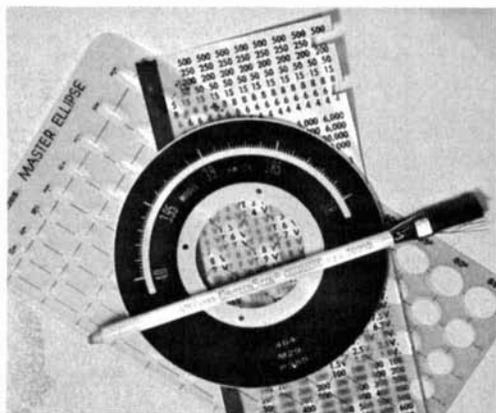
Some interesting variations of the circuit in fig. 1 may be possible if an additional driving transistor is tolerated.

Bill Conklin, K6KA

putting the HW-12 on MARS

The Heathkit HW-12A ssb transceiver can be modified easily for use on the 4-MHz Navy MARS frequencies without any electrical changes. Operation on Navy MARS requires a frequency range up to about 4050 kHz. In the HW-12A this is accomplished by changing the tuning range from the original 3800 to 4000 kHz to 3850 to 4050 kHz. This is done by re-adjusting vfo coil, L5, and the vfo

the new frequency range the driver grid coil, L2 (40-516) and the driver plate coil, L3 (40-513) must be unsealed. Peak the top slug of L2 at 4000 kHz and the bottom slug of L2 at 3900 kHz; L3 is peaked at 3950 kHz. Depending on component tolerance, you may have to change one of the two fixed-value power-amplifier tuning capacitors (C206 and C207) from 68 to 47 pF.



HW-12A dial-conversion kit.



Heathkit HW-12A with new MARS dial.

trimmer capacitor so the vfo tunes from 1.5433 to 1.7433 MHz (original vfo frequency range is 1.4933 to 1.6967 MHz).

To improve the vfo output level across

As a final touch, to maintain appearance and provide direct frequency read-out, the vfo dial is modified. A very professional appearance can be obtained by erasing the existing dial numbers with an ink eraser, using an ellipse template as an erasing guide. A fine-tipped eraser pencil works best (see photo). The black areas are easily removed from the white plastic dial. Black decals are then applied inside the erased areas at 3850, 3900, 3950, 4000 and 4050. A touch of clear plastic model paint over the decals completes the job.

I have had excellent results throughout the 4th Naval District with the modified HW-12A and a dipole antenna. The dipole consists of approximately 108 feet number-16 insulated wire, twisted around nylon sash cord for strength. It is centered with a 1:1 balun and RG-8/U coaxial cable; vswr at 4 MHz is 1.15:1.

David M. Stahley, K8AUH

crystal-controlled frequency markers

A simple frequency marker for your sweep generator can be built from several surplus crystals. Piezoelectric crystals function as highly-selective notch filters when placed in shunt with an rf signal, and have been used successfully in the grid and plate circuits of fm repeater receivers to short unwanted frequency components to ground.



fig. 2. Simple crystal-controlled frequency marker uses shunting characteristics of quartz crystals.

The crystal frequency marker unit in fig. 2 consists of several parallel-connected crystals mounted in a minibox. The output of the sweep generator is passed through the device to the circuit under test. Since energy at the resonant frequency of each crystal is shunted to ground, there is a suck-out for each of the crystals used in the circuit. In addition, if the crystals are overtone types, frequency markers are also shown at the harmonic frequencies.

The small amount of capacitance contributed by the circuit in fig. 1 tends to shunt the rf signal more and more as the sweep signal increases in frequency. This appears as a slight negative slope on the oscilloscope display.

Earnest A Franke, WA4ADK

high-voltage step-start circuit

Fig. 3 shows a fail-safe step-start circuit for the primary of high-voltage power supplies that is simple and effective, having been used for many years in various applications. With the present trend to higher and higher capacitances in power supplies this start circuit it a

simple precaution to extend the life of diodes and filter capacitors by reducing the initial surge charging current.

Furthermore, in the case of an overload, which may not react to other protective circuits, this step-start circuit will revert to its initial state, thereby providing a measure of protection. With appropriate connections this circuit may be used with either 120 or 240 volts ac.

Relay K1 is the contactor normally used to energize the high-voltage primary winding. As it closes a voltage drop will occur across R1. This voltage drop is adjusted to suit the requirements of the power supply. The voltage drop across R1 diminishes after the initial surge, and relay K2 is energized, shorting out R1. On a 240-volt system K2 may be connected to the center-tap of the power transformer, or to the neutral.

Marv Gonsior, W6VFR

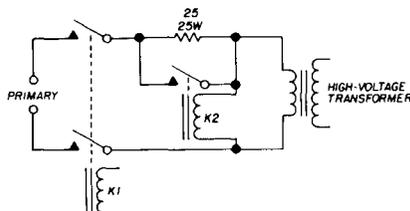


fig. 3. High-voltage step-start circuit.

rotator improvement

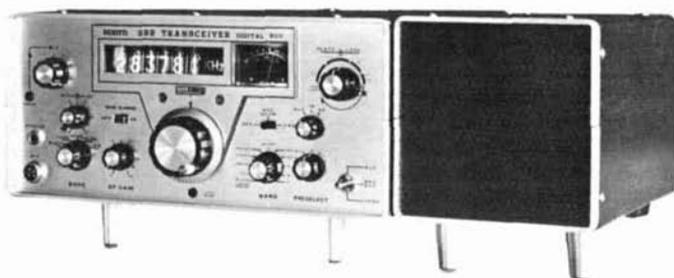
If you have an Alliance T-45 rotator (or similar non-automatic rotator) a simple circuit modification will eliminate the tiresome task of holding down the control bar with your finger. Just install a dpdt switch, with center off, in parallel with the contacts on the control-box switch. Switch mounting is a bit of a problem since there isn't room enough in the T-45 control-box to accommodate the new dpdt switch. For my control box I put the added switch in a small metal file box complete with direction labels (clockwise and counter-clockwise). Now I have one hand free for tuning the rig while I run the antenna around.

Ed Mitchell, WA0VAM

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ST-6 RTTY demodulator



HAL Devices now offers a standard wired ST-6 RTTY Terminal Unit. The unit is enclosed in a very attractive cabinet with all control and connector functions clearly labeled. Because of the standardization required to produce the silk-screen from which all front and rear panels are labeled and drilled, wired units are available *only* in the maximum feature configuration for both shifts with autostart and anti-space. An additional feature of all wired units is the inclusion of meter-switching to allow use of the meter for both a tuning indication and to indicate loop current.

The cabinets are 3½" high x 17" wide x 12" deep and are available in rack-mounted or table-top configurations. The top and bottom panels of the cabinet are easily removable for access to the circuit boards and other components. These units are wired by skilled professional

personnel, and all tuned circuits are aligned with an electronic counter to a tolerance of 5 Hz for the 850-Hz shift circuits and 3 Hz for the 170-Hz circuits. All adjustments are pre-set at the factory and all modes and features of each unit are tested in actual operation, receiving and printing RTTY signals.

All wired HAL Devices products carry a 1 year warranty against defects in materials and workmanship. The wired ST-6 is priced at \$280.00 plus postage; shipping weight is approximately 23 pounds. When ordering be sure to specify which cabinet style, rack or table-top, is preferred and include sufficient remittance to cover postage and insurance. Limited staff time at HAL Devices as well as the great care (and therefore time) taken in the construction of each unit means that delivery times will be long, and at least 1 month should be allowed for each wired ST-6 ordered. Wired units are constructed on an as-received basis, the earliest orders being processed and constructed first. HAL Devices will acknowledge receipt of all orders for wired units and will indicate the projected delivery date at that time.

HAL Devices also offers ST-6 parts kits for the amateur who wants to build his own. To order, write to HAL Devices, Post Office Box 365, Urbana, Illinois 61801. For more information, use *check-off* on page 94.

digital frequency meter

The Micro-Z FM-36 frequency meter includes all of the features that have made the FM-6 so popular — high quality and accuracy, ease of assembly, guaranteed operation, small size and cost — plus the added convenience of a third digit to simplify switching and readout.

This instrument is useful in the service shop for calibrating audio and rf signal generators or testing transmitter and receiver oscillators and multipliers. Simply connect the FM-36 to the output of your transmitter with the coax T-connector supplied, and your frequency is measured and displayed whenever you are on the air. In addition, a companion prescaler is available for vhf operation.

The FM-36 operates from audio frequencies through 35 MHz with input signals from 0.4 to over 200 volts. The circuit is completely self-contained with a 117-Vac power supply. The FM-36, factory assembled and tested, is \$164.50. The FM-36 kit, including all parts and detailed assembly instructions, is \$134.50 from Micro-Z Electronic Systems, Box 2426, Rolling Hills, California 90274. For more information use *check-off* on page 94.

cordless electric soldering iron

The new cordless electric soldering iron offered by the Technical Equipment Company provides an output of 40 watts with a heavy-duty 10 amp-hour NiCad battery. The Express 2000 features instant heat, negligible magnetic field, two interchangeable tips (25- and 40-watt), complete portability, and is solid-state-device proof — battery operation assures complete electrical isolation.

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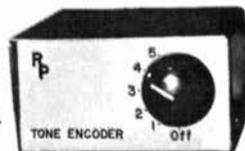
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fiberglass mobile antennas

The new Shakespeare fiberglass antennas are a breakthrough in the design of mobile radio antennas. Two models are available: the style 456 for low-band, 25 to 57 MHz; and the style 455 for high-band, 144-174 MHz. Every effort has been made by the Shakespeare engineers to design an antenna that delivers the best electrical and mechanical performance without any compromises.

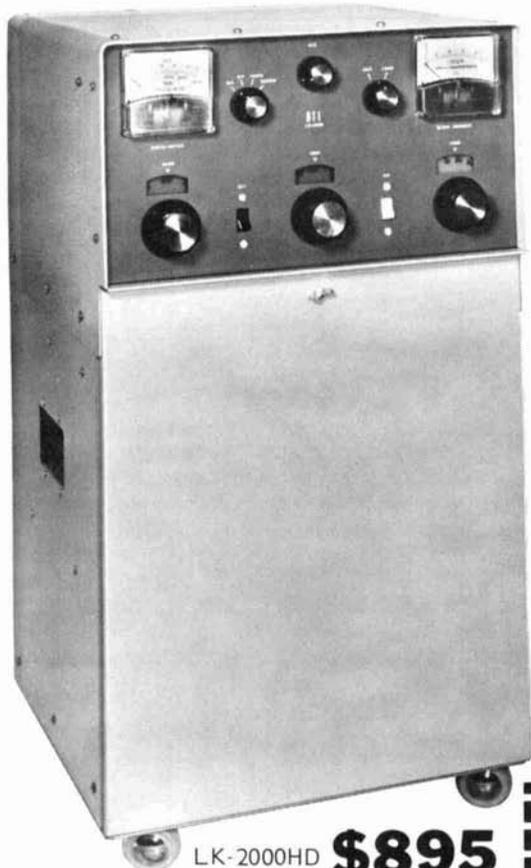
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The style 455 is a 5/8-wave antenna, power rated at 100 watts, with a power gain of 2.7 dB. Standing-wave ratio is 1.3:1 or less when cut to exact frequency; input impedance is 50 ohms. Bandwidth is ± 2.5 MHz for 2:1 swr. Frequency range is 144 to 174 MHz. For more information, use *check-off* on page 94, or write to Shakespeare, Post Office Drawer 246, Columbia, South Carolina 29202.

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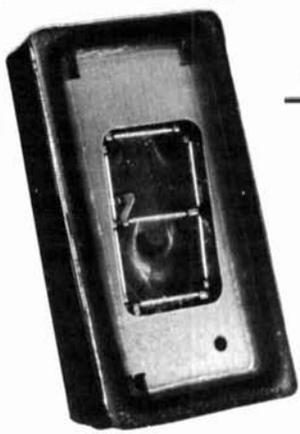
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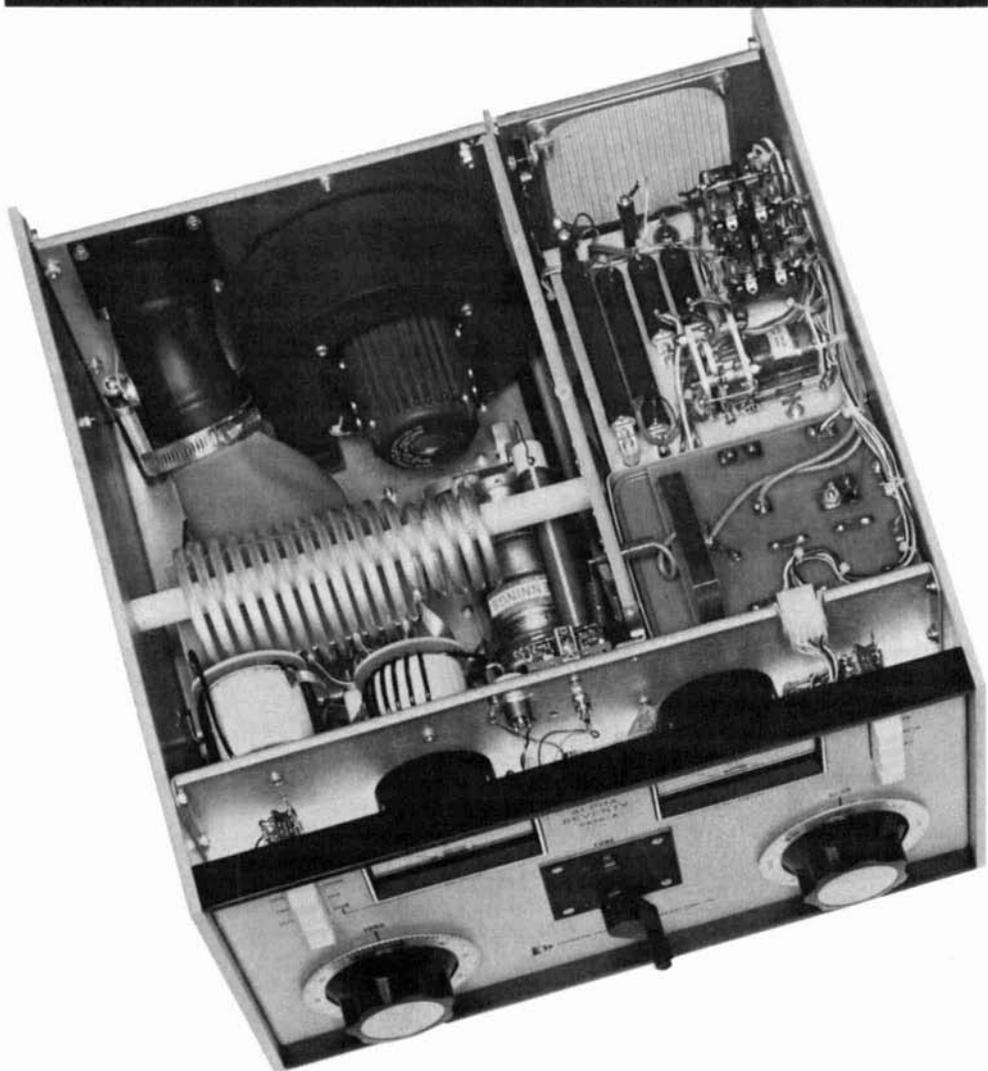
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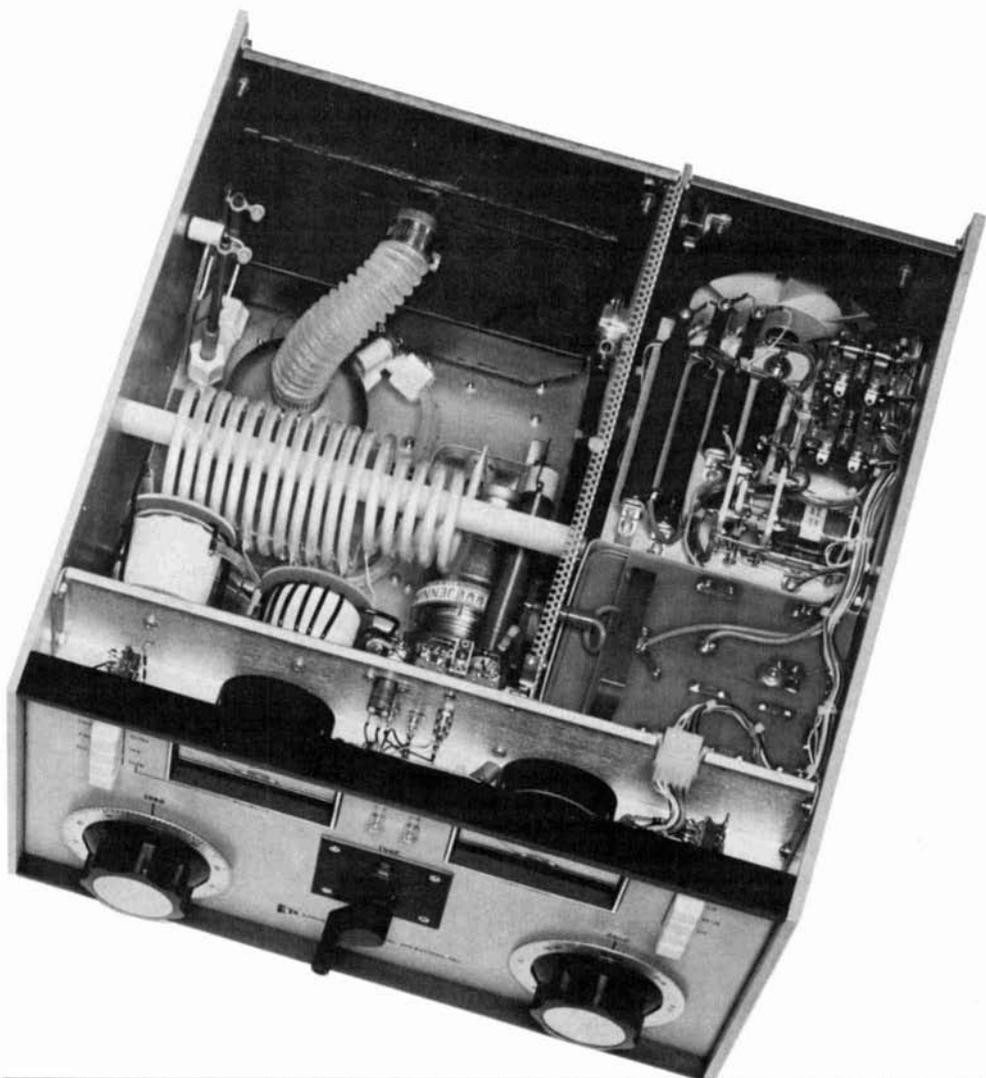
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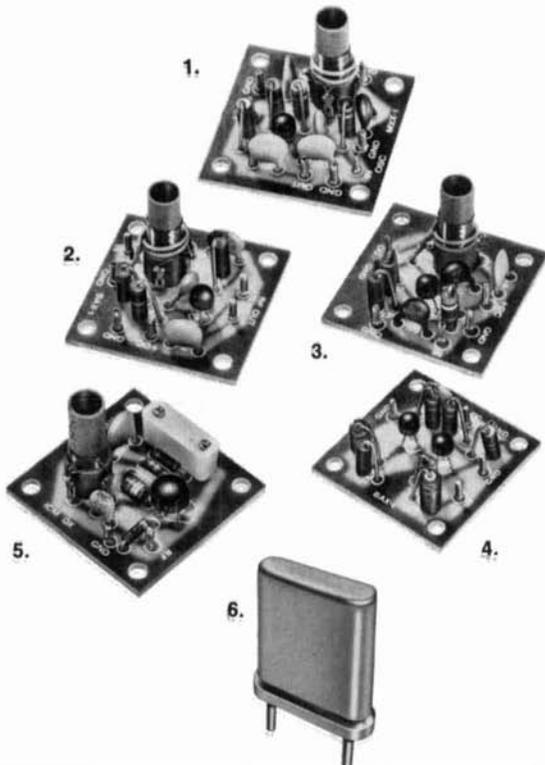
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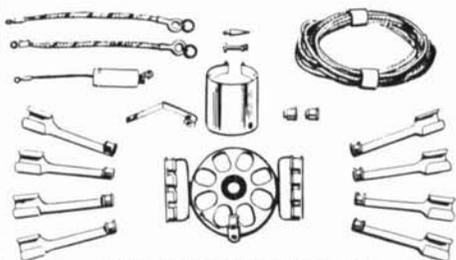
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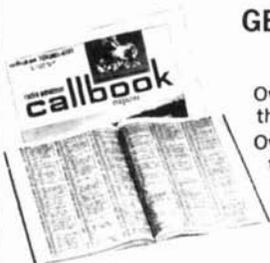
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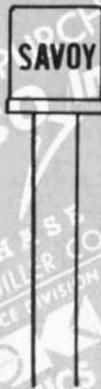
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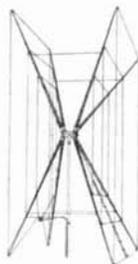
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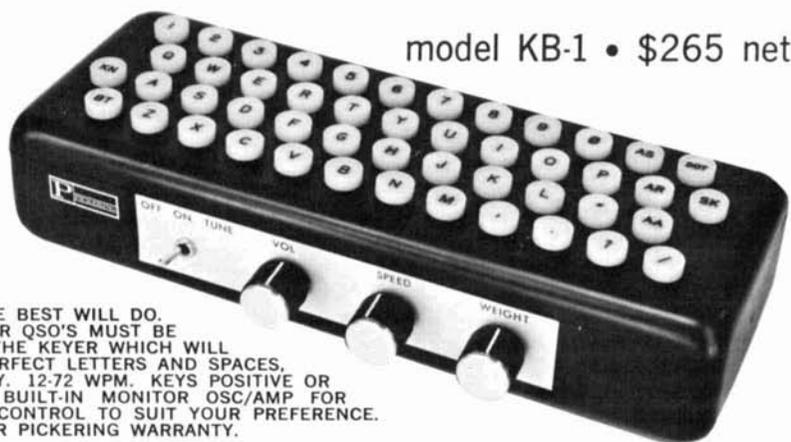
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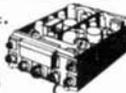
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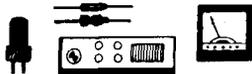
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MECHANICAL FILTERS: 455 Khz. 2.1 Khz \$18.95. 300 Hz \$22.95. J. A. Fredricks, 314 South 13th Ave., Yakima, Washington 98902.

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NEW SIGNAL-ONE, unopened carton, warranty, latest model. Sell/trade, want Collins, Drake, Don Payne, K4ID, Box 525, Springfield, Tenn. 37172. Nites (615) 384-5643, days (615) 384-5573.

WORLD QSL BUREAU — see ad page 90.

JAMAICA (6Y5) Reciprocal licensing authorizations are now available to W/K amateurs. Write Ham Radio Magazine for application.

TRI-STATE PICNIC, Pulaski Park, West Gloucester, RI (off Rt. 44), 9:30 a.m. to sunset, September 19. Trunk sales. Bring your own picnic. Talk in K1ZKR on 50.36. RI Swamp Yankee Amateur Radio Club & Eastern Conn. Amateur Radio Club.

WANTED: ELMAC EF68 XMTR, PMR-8 receiver and matching mobil power supply. State price and condition of equipment. Write: C. E. Smith, P. O. Box 1224, Rosamond, California 93560.

SELL SR150 with HBAC. Factory DC and mobile mount. Real good. HW100, HP23 AC with Swan dial, like new, \$270. GT550 and matching AC and speaker, almost new, \$350. HW12A, AC HP23 \$125. All FOB and with manuals. Richard Schark, 417 North Ferry Ottumwa, Iowa 52501.

THE SOUTH JERSEY RADIO ASSOCIATION will sponsor its annual gala Hamfest on Sunday, September 12, 1971, 11:00 a.m. to 5:00 p.m. at Molia Farm, Malaga, New Jersey (Rain date — September 19th). Picnic area, parking facilities, many prizes, swap shop and much more! Check Frequency 3.930, 50.3 and 145.3 MHz. Molia Farm is near intersection of Route 40 and 47 near Malaga, New Jersey. Advanced donation is \$2.00 per family until September 6. General donation at the gate is \$3.00 per family. Obtain advance tickets from Joe Duffin, W2ORA, 247 Kings Highway, West, Haddonfield, New Jersey 08033. Checks should be made out to South Jersey Radio Association.

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WANTED Ham Radio back issues April, July, 1969, April, 1970. Good condition. Top payment, W7AGE, 10724-11th Avenue N.W., Seattle, WA 98177.

LOOKING FOR FULL-TIME EMPLOYMENT? If you're a self-starter able to sell excellent Electronic Courses, there are jobs available throughout America and Canada. Write to Bill Welsh (W6DDB), 234 S. Orchard, Burbank, CA 91506.

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

WANTED: TAYLOR 3106/3107 wind and speed direction indicators. Quote condition and price. O. J. Supliski, WB2SLQ, 53 Hayward St., Yonkers, N. Y. 10704.

TELETYPE GEAR: SASE for list. Kleinschmidt RO, 100 wpm \$50.00. Telecommunications, Box 4117, Alexandria, Va. 22303.

VHF NOISE BLANKER — See Westcom ad in Nov., Dec. '70 and Mar. '71 Ham Radio.

OLD TIME RADIO SHOWS. SASE. Box 724, Redmond, Washington 98052.

PRINT CIRCUITS: oscillator, dividers chains, counter control unit, amplifiers, and 100 KC oscillators; wire and tested or kits. Write for catalogue: K Enterprises, 1401 N. Tucker, Shawnee, Okla. 74801.

SALE: RCVR RCA CRM-66A tunes 80kc to 30mc sliderule dial triple conversion provision for mechanical filters AM/SSB/CW. Excellent condition. Cost over \$1000. Best offer takes it COD. Foss, 1517 N. Main, Walnutcreek, California 94596.

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

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

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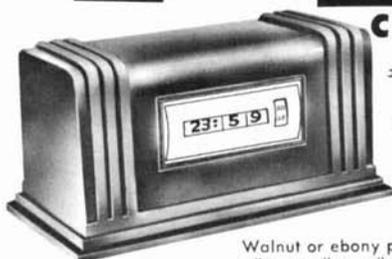
MARN Mosaic Amateur Radio Net an association of Masonic amateur radio brethren and members of the appendant Orders. Dedicated to service to mankind and international good will. Write for information. MARN, 11049 Avenue E, Chicago, Illinois 60617.

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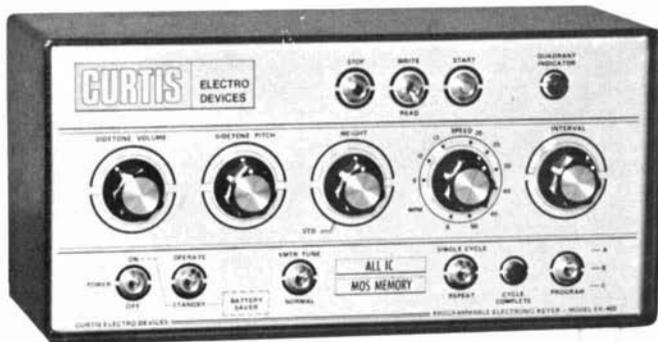
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RADIO SOCIETY OF ONTARIO CONVENTION 1971. Hosted by Guelph Amateur Radio Club. October 22-23, 1971. Holiday Inn, Hespeler, Ontario. Jcts. Hwys. 401 and 24. 46 miles from Toronto, 174 miles from Windsor. For further details contact D. Gore, VE3DGA or R. Jenning VE3CZE, Box 342, Guelph, Ontario.

MANUALS: \$5 each, Receivers, XMTRS. Ratt test equipment, R390/URR, R388/URR, AN/GRC26A, AN/MRC2-D and numerous others. SASE for list. B. Brunges, 581 Continental Dr., San Jose, Calif. 95111.

FOR SALE: GALAXY V, \$230; speaker console \$18, AC supply \$85, HW-16 \$85. All mint. Steve Harbin, Box 431, Clinton, S. C. 29325.

THE PUGET SOUND COUNCIL of Amateur Radio Clubs will issue an operating achievement award signed by Governor Daniel J. Evans, for contacts made during Washington State Amateur Radio Week, September 4th to 12th, 1971. Out-of-state amateurs must work ten Washington stations, and in-state amateurs must work twenty other Washington stations during this week. Send list of stations worked, their locations, dates of contacts, and your name, call, and address to: The Puget Sound Council of Amateur Radio Clubs, 12306 80th Avenue East, Puyallup, Washington 98371. An SASE would be appreciated.

VIRGIN ISLANDS TRANSMITTING AND LISTENING SOCIETY (VITALS) will conduct a minidexpedition during the period 9-17 October to PJ8/FS7/VP2 working/MM as well on 20-15-10 CW/SSB. QSL sase to Command Communications, Box 3374, St. Thomas, VI 00801. Principals are: KV4BV, KV4EY, KV4FR and other possibles.

AUDIO FILTERS: Knock down that background noise. KOJO SSB, AM, and CW filters do the job. Write for free brochure and see how serious DX boys hear them. KOJO, Box 7774, 741 E. Highland Ave., Phoenix, Arizona 85011.

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

THE AMATEUR RADIO CLUBS of New Mexico will sponsor the New Mexico HAMVENTION 1971 on September 17, 18 and 19, 1971. Convention headquarters will be the Sheraton Motor Hotel on East Highway 66, Albuquerque, New Mexico. The Program: Antenna Session, SSB, LASER Communications, DX, QCWA, Traffic, VHF/FM., Ladies Luncheon & Fashion Show, AREC/RACES, MARS, Manufacturers Displays, Banquet with top speakers. Many prizes: Flea Market/Swapfest all day Sunday. Talk-in Frequencies — 3940 — 7255 — 146.34/146.94. Pre-registration — \$8.50, (includes banquet meal) at door \$12.00. Contact: N. M. HAMVENTION, Box 14381, Albuquerque, N. M. 87111.

COLLINS 75A — Receivers Tuning Knob, 6 to 1 ratio, \$8.00 Postpaid. W6YO, 1416 7th Avenue, Delano, California 93215.

NOVICE CRYSTALS: 40-15M \$1.60; 80M \$2.10. Free flyer. Nat Stinnette Electronics, Umatilla, FL 32784.

THE FOUNDATION FOR AMATEUR RADIO, INC., an organization consisting of 27 amateur radio clubs all located in the greater Washington, DC, metropolitan area, will hold its annual HAMFEST on Sunday, 24 October 1971 from 10 a.m. until 5 p.m. at the Gaithersburg Fairgrounds in nearby Gaithersburg, Maryland just off Interstate 75.

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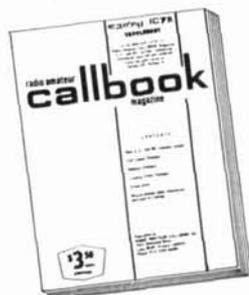
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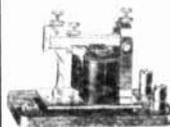
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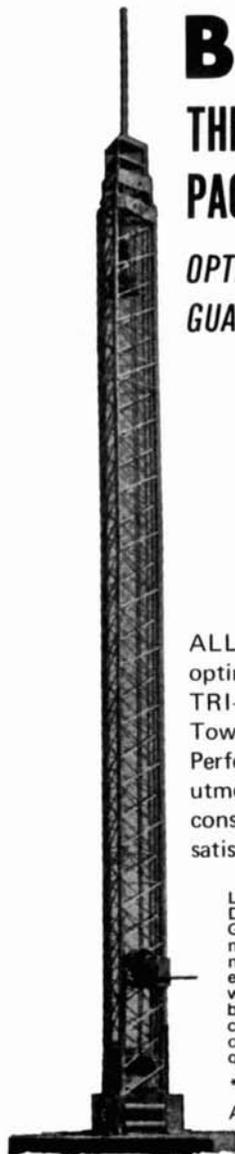
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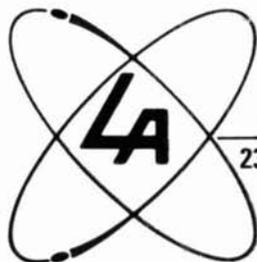
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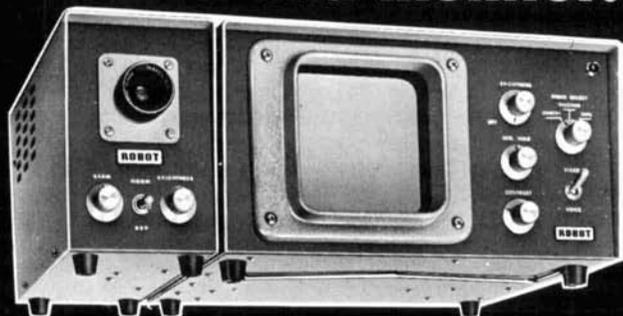
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