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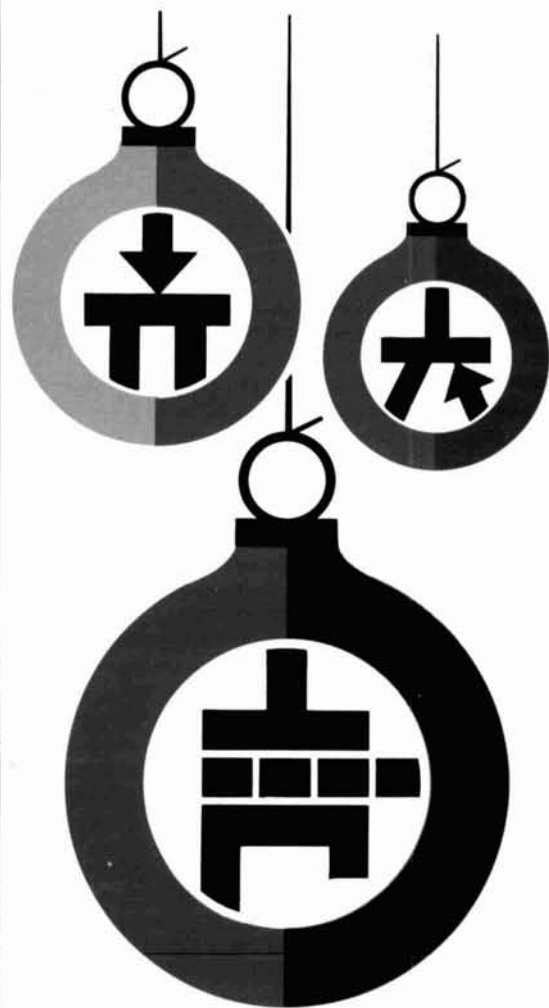
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focus
on
communications
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ham radio

magazine

DECEMBER 1969



this month

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volume 2, number 12

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ham radio magazine is published monthly by Communications Technology, Inc., Greenville, New Hampshire 03048. Subscription rates, world wide: one year \$6.00, three years, \$12.00. Second class postage paid at Greenville, N.H. 03048 and at additional mailing offices.

Foreign subscription agents: United Kingdom: Radio Society of Great Britain, 35 Doughty Street, London WC1, England.

All European countries: Eskill Persson, SM5CJD, Frotunagrand 1, 194 00 Upplands Vasby, Sweden.

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ham radio is available to the blind and physically handicapped on magnetic tape from Science for the Blind, 221 Rock Hill Road, Bala Cynwyd, Pennsylvania 19004. Microfilm copies of current and back issues are available from University Microfilms, 313 N. First Street, Ann Arbor, Michigan 48103.

Postmaster: Please send form 3579 to **ham radio** magazine, Greenville, New Hampshire 03048.

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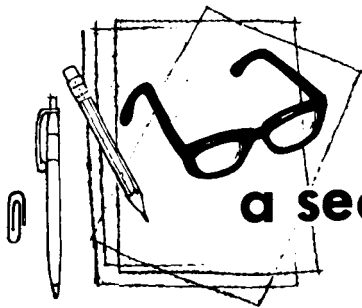
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William G. Blankenship, Jr., WA4GNW

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a second look

by Jim
fisk

The editor of a technically oriented magazine like **ham radio** wears several hats. I could occupy the whole page describing the details that require attention to keep the magazine running smoothly. But I'd like to talk for a moment about one very important editorial task that means the difference between a technical magazine that instills confidence in the reader, and one that doesn't. This task, which I share with my staff, is that of researcher and seeker of truth.

Most of the articles published in **ham radio** are contributed. Authors range from enthusiastic hams who want to share an idea, to fellows with engineering backgrounds (who also want to share an idea). I think this is fine, and I welcome the output of everyone who is interested in contributing something that will benefit all hams.

Budding authors often ask, "What kind of articles are you looking for?"

That question is difficult to answer since many new manuscripts come in every day, but generally speaking, I am looking for simple solid-state construction projects that the average fellow can build in one or two weekends. Larger construction projects are also welcome, but the average **ham radio** reader must split his leisure time between amateur radio and other interests, so he doesn't have the time to build a Chinese copy of a complex piece of equipment.

When I read an article contributed to **ham radio**, the first thing I look for is interest value. If the contribution passes this test, the next thing I look for is technical accuracy and attention to detail.

The contributed article doesn't have to be a literary masterpiece. If you have a good idea; if it's well documented; if the illustra-

tions and technical discussion are clear and accurate—you probably have a winner!

My staff and I are fairly adept at ferreting out technical oversights and inconsistencies, but of course, we can't catch them all. Despite research and keeping the mailman busy between our editorial office and the author, errors occasionally do creep into the magazine. As a contributing author, you can help reduce the number of "short circuit" items that are published from time-to-time.

For example, when you draw your illustrations, go over each component, each wire, and each connection. Take another look at numerical values. A misplaced decimal point in a component value can mean the difference between a circuit that works and one that can cost the builder a small fortune in burned-out parts.

Not only does this cause considerable misery to the builder, but as publishers **we** are taken to task for the error. Result: a "short circuit" item must be published in a later issue. This takes care of the initial problem, but by then, considerable damage could have been done.

If you prefer to read **ham radio**, rather than write for it, you can help by telling me the kind of article that you like. If you have a pet project in mind, or an old project that could be updated with transistors or integrated circuits, let me know about it; I'll pass the idea along to one of our authors.

We are continually trying to improve **ham radio**, but we can only do that successfully if we hear from you, the reader, so keep those cards and letters coming in.

Jim Fisk, W1DTY
editor

From gigahertz to nanoseconds in one simple switch.



You might expect a good high-power oscillator in the gigahertz range would make a good high-power switch in the nanosecond range. Sort of flip side of the coin. What makes an Eimac planar triode good at one thing makes it good at another.

Eimac planar triodes, shown here actual size, are so versatile you can use them to switch very short pulses at very high peak powers.

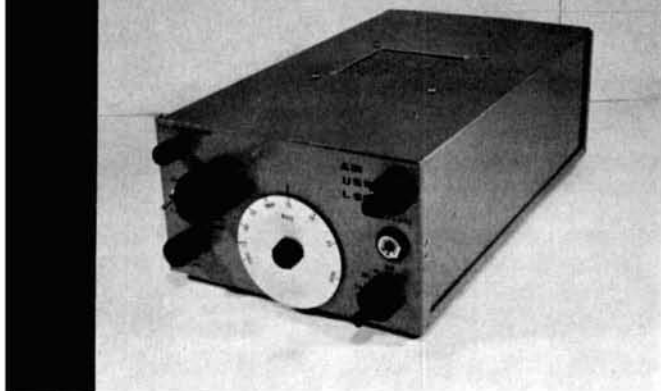
In areas where solid state devices simply can't compete.

For example, an Eimac planar triode will generate 10-nanosecond pulses, or will switch with risetimes as short as 1 nanosecond, in circuits for solid-state-component test equipment. For testing Gunn, Impatt and LSA devices they'll replace bulky switch tubes and power supplies at voltages as high as 10 kV without danger of burnout. Or in ECM applications you can use them to trim space and weight without sacrificing reliability.

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solid-state receiver for 160 meters

Although this receiver
was designed
for the 1.8-MHz band,
it contains
many interesting
circuits
that could be applied
to higher frequency
units

John K. Gotwals, W3TNO, 419 West Stadium Avenue, West Lafayette, Indiana, 47906

Recent changes in the FCC rules governing amateur activity on 160 meters have prompted renewed interest in 160-meter operation. Since many ham-band-only receivers do not cover 160, I felt there should be a lot of interest in a high quality, solid-state receiver capable of tuning 160 meters. The receiver presented here uses many of the latest semiconductor devices, and many of the design ideas and circuits would be equally applicable to higher-frequency receivers.

A block diagram of the 160-meter receiver is shown in **fig. 1**. Note that there is no rf stage ahead of the mixer. This omission is not an attempt to simplify the receiver but to improve its over-all performance. Several years ago recent receiver developments were reviewed,¹ and the authors pointed out that to minimize spurious responses, no rf stage is needed, or desired, at frequencies below 15 MHz.

In the receiver shown in **fig. 1** a 455-kHz i-f was chosen so I could try the Murata CF-455 ceramic filters.² These filters are compact, exhibit good shape factors and are easy to use with simple resistance-coupled transistor circuitry. Collins mechanical filters could be used as well.

variable attenuator

A schematic of the variable attenuator and high-pass filter is shown in **fig. 2**. The attenuator can be varied from zero to 40 dB in 10-dB steps³ and is used if you are listen-

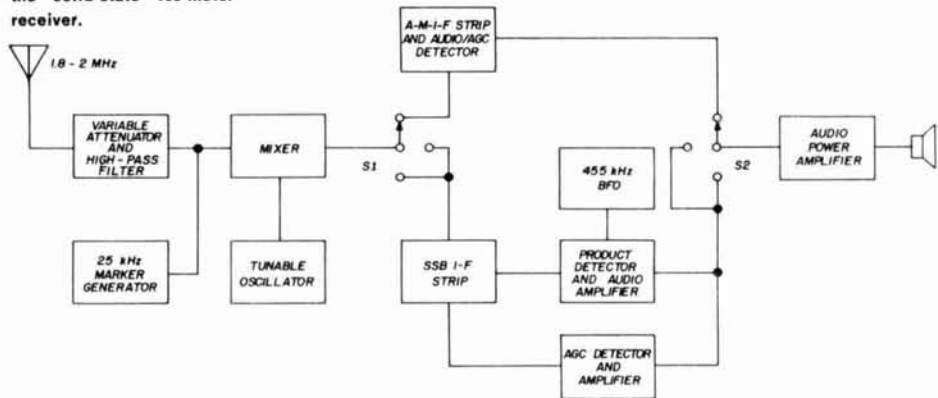
ing to local stations or if you want to drop out weak signals and hear only the strong ones.

The high-pass filter is used to eliminate cross modulation and intermodulation from local broadcast stations. Although the mosfet mixer has excellent square-law characteristics, you still need some front-end rejection of the extremely strong broadcast signals present on a long 160-meter long-wire antenna.

down corner frequency is 1800 kHz. At 1604 kHz, response is down 45 dB. An excellent discussion and application of modern network synthesis to the design of low- and high-pass filters is given by Wetherhold.⁴ The serious filter designer will also take a look at the work by Geffe.⁵

I used 5 percent mica capacitors in my filter, but performance closer to the theoretical would be obtained if more expensive 2 percent mica capacitors were used. Both

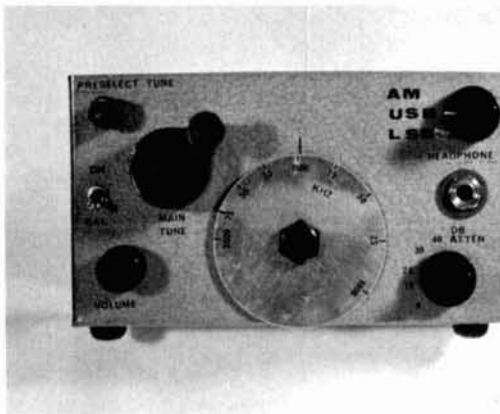
fig. 1. Block diagram of the solid-state 160-meter receiver.



The high-pass filter is an elliptic function type with response zeros at 918 kHz, 1586 kHz and 1415 kHz. The zeros are the frequencies where the theoretical attenuation becomes infinite. The theoretical passband ripple is less than 0.2 dB, and the 0.2 dB

types are available from Allied Electronics. The Q of the inductors should be at least 100; I used Ferroxcube 4C4 pot cores. They have the advantage of being adjusted approximately ± 6 percent. In addition, they have a negative linear controlled temperature coefficient that compensates silver-mica capacitors. They cost about \$2.50 apiece in the 14 mm size. Write to Ferroxcube⁶ for more information.

Receiver front panel.



dual-gate mosfet mixer

A schematic of the mixer front end is shown in fig. 3. The data sheet for the 3N141 shows a mixer biased to 3 mA with both gates at about the same potential. In a companion application note,⁸ H. M. Kleinman mentions two requirements for spurious response elimination: clean oscillator waveform and properly adjusted operating conditions and signal levels. This means that biasing voltages are important. Also, local-oscillator injection should not be too high.

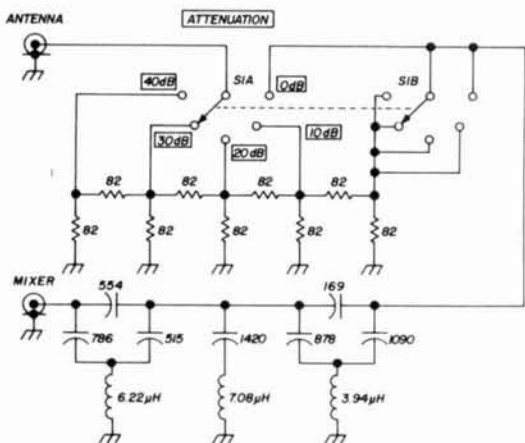


fig. 2. Variable attenuator and high-pass filter for the solid-state receiver. Input and output impedance of the filter is 52 ohms. With Ferroxcube 1408C-A25-4C4 pot-core assembly, 1408HD hardware and 1408F1D bobbin, 13 turns no. 24 enameled was used for the 3.94 μ H inductor, 16½ turns for the 6.22 μ H inductor, and 17 turns for the 7.08 μ H inductor. Higher Q could be obtained by using 19/46 Litz wire.

very important. As noted above, the stage should operate in class A for minimum spurious response. Fortunately, class A operation is also important to frequency stability. In simple oscillators an important source of frequency instability is associated with the intermodulation of harmonic frequencies which are produced by the limiting that takes place if agc is not used.¹¹ The Clapp oscillator in this design has been linearized by adding an agc circuit; frequency stability, with variable supply voltage, is improved by about 15 times.

The oscillator circuit is shown in fig. 4. Diode D1 linearizes the oscillator as follows:



As a compromise between conversion gain and spurious-response generation, I used a 2.5 volt p-p signal to the mixer.

I used electronic tuning for the input circuit so I would have complete freedom in the placement of the mixer module. If you're interested in using tuning diodes in the place of mechanical tuning, Motorola has two helpful application notes.^{9,10}

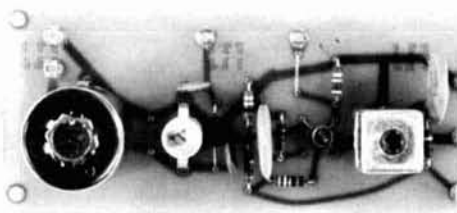
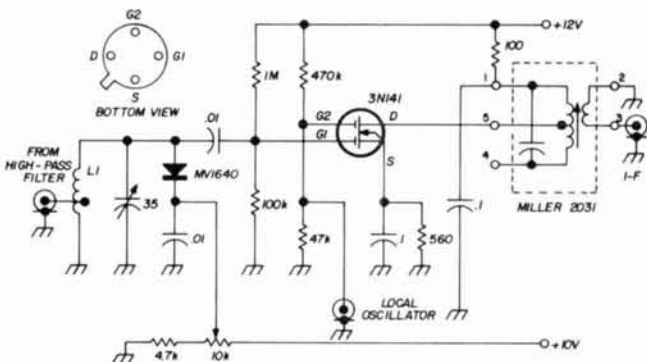
local oscillator

The stability of the receiver is determined by the local oscillator, so circuit design is

fig. 3. Dual-gate mosfet mixer. L1 is 115 μ H and consists of 41½ turns no. 24 on Ferroxcube 2213C-A60-4C4 pot core, tapped 1 turn from cold end.

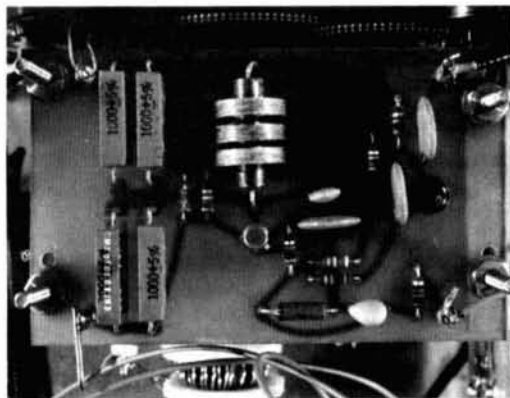
High-pass filter uses high-Q pot-core coil forms.

when power is applied, the gate is at the same potential as the source so forward transconductance is maximum. As oscillations build up, D1 clamps the gate below ground; this charges up capacitors C1 and C2 and results in a negative dc voltage at the gate, and the forward transconductance of the device is lowered until equilibrium is reached.



Without D1 in the circuit, the 3N152 would have to provide its own limiting, and this could only be done with the mosfet operating in a nonlinear mode. W2YM uses a diode in a similar circuit and reports that it stabilizes the oscillator.¹² Capacitor C3 is selected to provide the desired injection level at the mixer.

For best operation, the Q of L1 should be high. I used two Micrometals T94-2 toroid cores in series.* The tuning capacitor is from a surplus ARC-5 transmitter. This capacitor is an excellent choice for any vfo. Since the capacitor is quite rigid, I mounted all the vfo components on the capacitor frame. The gears that are an integral part of the ARC-5 capacitor are used for the dial.



Vfo board is mounted on top of the ARC-5 tuning capacitor. The series toroidal coils are mounted on a 1/4" brass bolt which is soldered to the capacitor frame. Tefflon pads are used to clamp the coils.

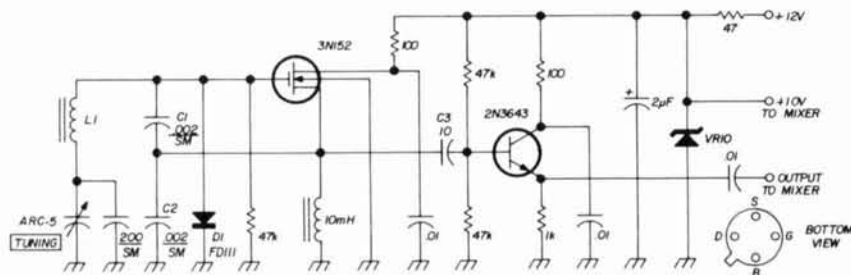


fig. 4. High-frequency oscillator. L1 is two Micrometals T94-2 toroids in series, 41 turns no. 22 on each.

a-m i-f strip and detector

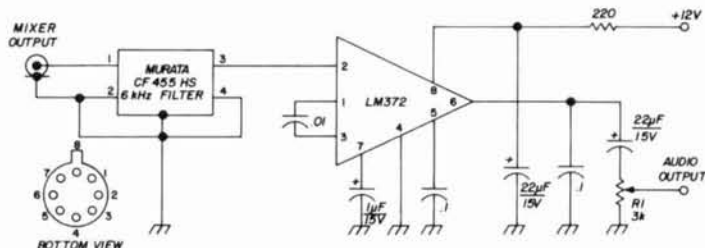
The a-m i-f strip shown in fig. 5 uses a unique integrated circuit, the LM372 manufactured by National Semiconductor.¹³ This IC is an i-f amplifier, a-m detector and an audio amplifier with self-contained agc. This gem will take an amplitude-modulated

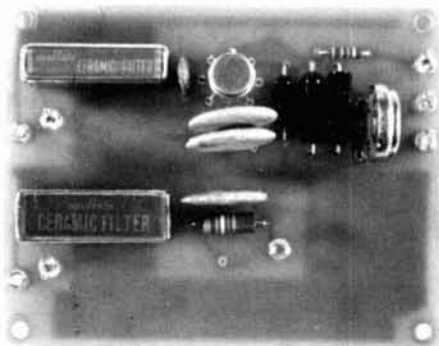
rf signal at frequencies up to 2 MHz and give you 0.8 V p-p audio output. The agc provides an essentially constant output as the rf input varies over the range from 50 microvolts to 50 millivolts.

In the photo of the a-m i-f strip the 3- and 6-kHz Murata ceramic filters are on the left. The 6-kHz filter is used with the a-m i-f system, and the 3-kHz filter is used for ssb. Resistor R1 is adjusted so that maximum

*Micrometals toroid cores are available from Amidon Associates, 12033 Otsego Street, North Hollywood, California 91607.

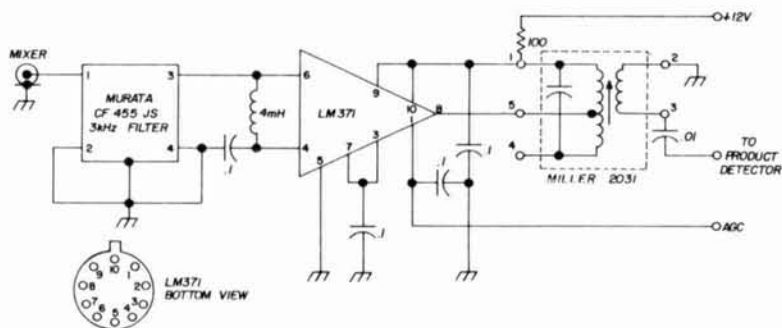
fig. 5. A-m i-f strip uses a communications-type integrated circuit, the National Semiconductor LM372. R1 is adjusted for 200 mV output.





A-m i-f board.

fig. 6. Single-side-band i-f system requires an external agc input from the agc circuit shown in fig. 9.



audio output is 200 mV (200 mV drives the audio-output stage to full output).

ssb i-f strip

The ssb i-f strip shown in fig. 6 is based on the use of an LM371 integrated circuit. The LM371 is quite versatile and may be used as an amplifier from dc to over 100

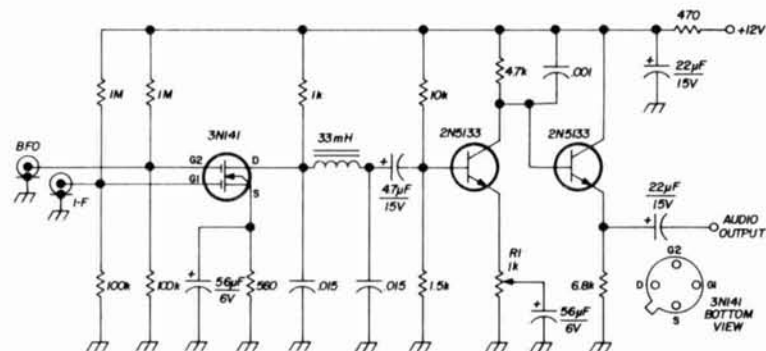
MHz. However, since this is a "first-generation" IC, agc detection and a ssb product detector must be furnished externally.* One of the big advantages of using the LM371 is that you don't have to worry about internal feedback. No neutralization is needed, even at 100 MHz. However, proper shielding must be used between input and output.

The LM371 data sheet shows the input and output impedances of the device over its complete operating range. However, for my application on the relatively low frequency of 455 kHz, I didn't worry about a

perfect match, and I used readily available i-f transformers.

*A newer device, the National Semiconductor LM373 i-f strip, is a broadband communications IC capable of performing the diverse functions required in a-m, fm and ssb receivers and transmitters. Simple external connections convert the i-f strip from one mode to another. The LM373 has a self-contained audio agc system with fast attack and slow release.

fig. 7. Product detector and audio amplifier.



product detector

A schematic diagram of the dual-gate mosfet product detector is shown in fig. 7. An adjustable-gain audio amplifier is coupled to the output of the product detector and is used to provide the same audio output as the a-m i-f system. Resistor R1 is adjusted so that the gain of the ssb i-f

The correct crystal frequencies are determined by the i-f filter. Although most single-sideband operation on 160 meters is confined to lower sideband, now and then you hear a station on upper sideband, so it pays to be able to receive either.

The diode in the gate circuit of the 2N4360 oscillator linearizes the oscillator

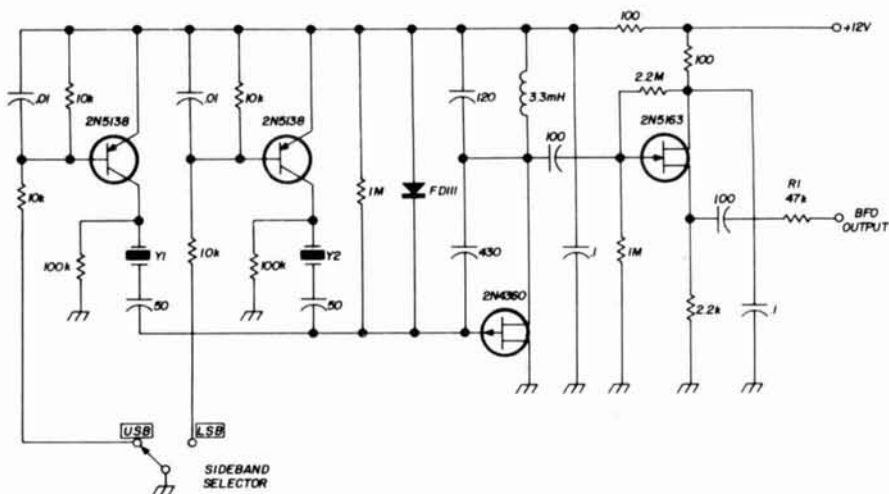


fig. 8. Beat-frequency oscillator uses electronic crystal switching. R1 is selected for 2 V p-p at the gate of the product detector.

strip (with no agc) is the same as that of the a-m i-f strip. The product detector is biased the same as the high-frequency mixer—at 3 mA drain current. This product detector has very low intermodulation distortion and actually performs much better than the diode type in my commercial receiver. Let me hasten to add, though, that diode product detectors are capable of excellent performance if they are properly designed.¹⁴

beat-frequency oscillator

The crystal controlled bfo shown in fig. 8 uses electronic crystal switching. The circuit could be simplified if a mechanical switch was used. However, it seemed to me that the flexibility of chassis layout outweighed the disadvantage of two extra 2N5138 transistors and a few extra resistors and capacitors.

and results in an extremely clean waveform. The 2N5163 source follower isolates the oscillator stage from any loading by the product detector. Resistor R1 is selected for 2 V p-p at the gate of the product detector.

Bfo, product detector and audio amplifier board.



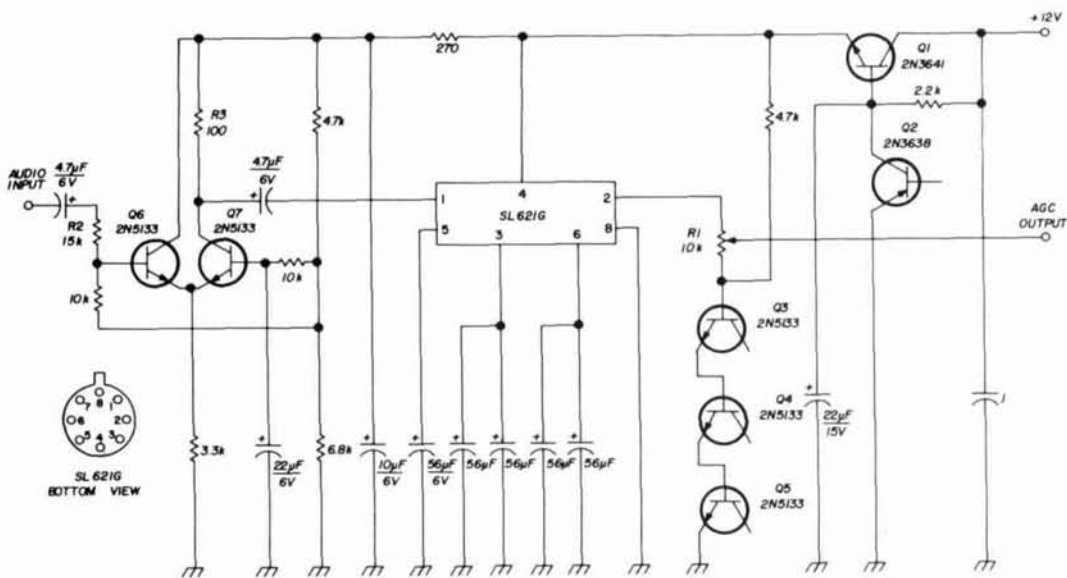


fig. 9. This versatile ssb agc circuit is based upon a communications integrated circuit, the Plessey SL621G.

The i-f amplifier, product detector, low-level audio and bfo are all mounted on the same board as shown in the photograph. However, in retrospect I would recommend that the i-f amplifier and its associated components be mounted on the same board as the i-f ceramic filter. In my layout the bfo radiates into the input circuit of the i-f amplifier. Although this doesn't appear to cause any trouble, moving the i-f amplifier to another board would prevent it from happening.

agc detector and amplifier

Good ssb and cw agc circuits are hard to find, although it's easy enough to list the kind of performance we're looking for:

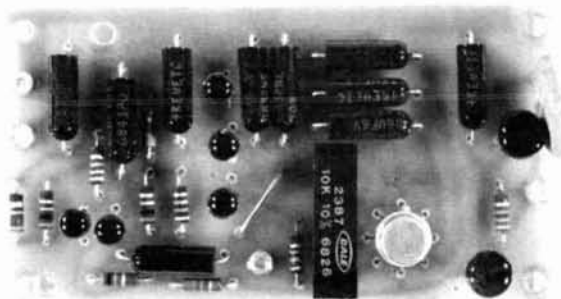
1. Fast attack, so the first word spoken doesn't blast out of the speaker.
2. Slow release—you don't want to hear the background noise between speech pauses—but not so slowly that the agc won't follow normal signal fading.
3. Immunity from noise interference.

The problem in designing a good agc system arises from the conflicts between the three basic performance requirements. The

literature has a number of "hang" agc circuits—and they sure hang up on noise! Circuits can be designed that will pretty well meet the three basic requirements, but if they're built with discrete components, they are quite complex.

The Plessey SL621G¹⁵ is an agc generator which comes pretty close to meeting the standards. It has fast attack and slow release for speech. By using two detectors, one with short rise and fall times, and one with long rise and fall times, the SL621G

Ssb agc board.



is able to prevent short noise pulses from "hanging up" the agc. If you are listening to a clear channel, and a noise spike comes along, the agc is activated only for the duration of the noise burst by virtue of the short-time-constant detector; the long-time-constant detector "remembers" the pre-noise agc level.

The same thing happens if a noise burst is superimposed on a speech signal. The short-time-constant detector initiates rapid agc action; when the noise pulse is over, the agc just as rapidly returns to the pre-noise level set by the long-time-constant detector.

A schematic of the complete agc module is shown in **fig. 9**. Don't be scared by its apparent complexity—2N5133 transistors are only 17¢ apiece. The circuit would be a lot more simple if I had used the other members of Plessey's SL600 series integrated circuits, but unfortunately industrial rated units (G suffix) have only recently become available.

Transistors Q1 and Q2 are used to reduce the 12-volt supply to the 6-volt level required by the SL621G. Q3, Q4, Q5 and resistor R1 make the agc output voltage compatible with the LM371 i-f amplifier. These components ensure that the agc output tracks the internal LM371 agc reference voltage as the temperature changes. Tran-



Audio power stage uses PA237 integrated circuit.

sistors Q6 and Q7 are connected as an emitter-coupled clipper and prevent the input coupling capacitor to the SL621G from charging up on strong audio peaks. Resistors R2 and R3 reduce the 200 mV input audio signal to the 10 mV level needed by the IC.

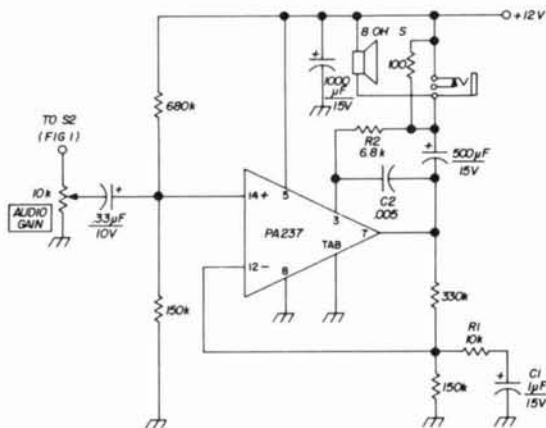
audio output stage

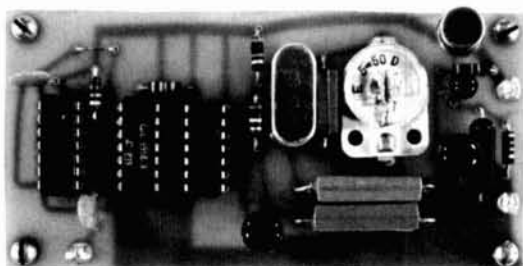
The audio output stage shown in **fig. 10** is driven to full output with a 200 mV input signal (full output is about 1 watt into an 8-ohm speaker). The output audio has very low distortion because of the generous amount of negative feedback that is used in the circuit. Resistor R1 sets the amount of feedback, the R1-C1 series circuit determines low-frequency cutoff. High-frequency cutoff is determined by R2-C2.

Resistor R2 also sets the quiescent current drawn by the quasi-complementary output of the PA237 IC. Since R2 is connected to the positive 12-volt supply (through the speaker) it protects the integrated circuit in case the speaker is not connected. Because of the positive feedback (load bootstrapping) that results when R2 is connected this way, the output has a larger voltage swing.

The complete audio output circuit board is shown in the photograph. Note that the 1000 μ F, 15 V capacitor shown in **fig. 10** is not on the board. I mounted it adjacent to the audio output module. This capacitor is needed for the current demands of the PA237 on audio peaks.

fig. 10. Audio output stage provides up to 1 watt into an 8-ohm speaker. Note that phone-jack frame is isolated from the chassis.





Crystal calibrator board.

marker generator

Since the 160-meter band is divided into 25-kHz segments, band markers every 25 kHz are a definite operating aid. I decided to use a 1 MHz crystal because it is more stable, smaller and less expensive than a 100 kHz unit. However, the cost of an extra divide-by-10 counter partly cancels some of the advantages. I opted for stability and used the 1 MHz approach.

The complete calibrator is shown in **fig. 11**. Transistors Q1, Q2 and Q3 reduce the 12-volt supply to 5 volts; Q4 is the 1 MHz oscillator. Since 25 kHz markers are desired, the crystal frequency must be divided by 40. This is done in two steps: the MC853P dual flip-flop divides by 4; then a Fairchild $C\mu L9958$ divides by 10. The square-wave

output of the 9958 drives a $TT\mu L9601$ one shot—this provides a 50 nanosecond pulse each time it is triggered.

The 50 ns pulse has rise and fall times of better than 10 ns, so it is rich in harmonics. Unlike calibrators with square-wave outputs, adjacent harmonics from a pulse generator have equal signal strength.¹⁶ Capacitor C2 is chosen to provide markers of the desired signal strength at the input to the receiver.

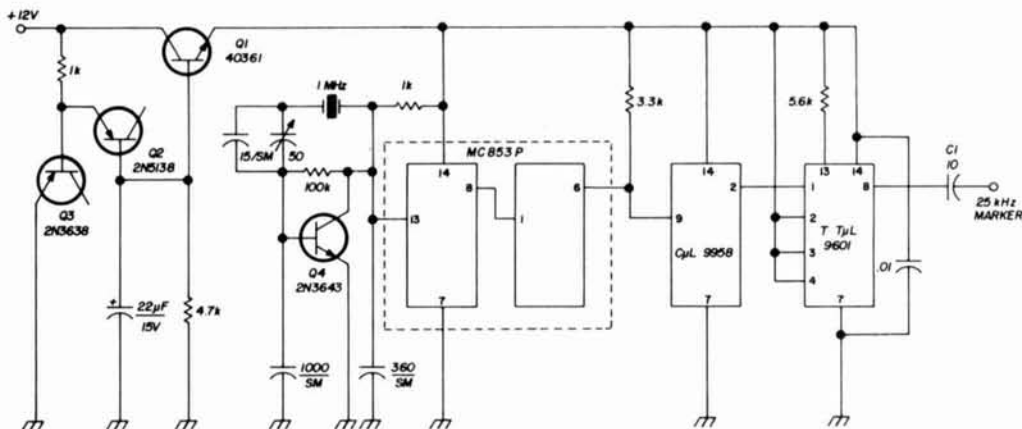
power supply

The 12-volt power supply for the receiver shown in **fig. 12** furnishes up to 400 mA at 12 volts. Since the audio output stage draws quite a bit of current during audio peaks, a stiff power supply is needed to prevent feedback between the audio-output stage and the other circuits through the power supply. The heart of this power supply is the Fairchild $\mu A723C$ voltage regulator IC. This IC has a built-in voltage reference of about 7 volts that is extremely stable with changes in temperature. The remainder of the IC functions as an operational amplifier.

As shown in **fig. 12**, the voltage reference, pin 4, is connected to the non-inverting input (pin 3). The inverting input (pin 2) is furnished with a voltage by R1 that is proportional to the output voltage. The operation of a power supply of this type has been discussed in **QST**.¹⁷

One feature of this power supply is the

fig. 11. Marker generator provides accurate 25-kHz markers from a 1 MHz crystal-controlled oscillator.



use of foldback current limiting. With most short-circuit-proof power supplies, the dissipation of the series-regulating transistor Q1 is quite high when the output is shorted to ground. This is because the voltage across the transistor is equal to the supply voltage, and the current supplied by Q1 is the full-load value. Thus, the power dissipated by Q1 during an output short circuit is three to four times higher than the power

R2 and R3 should be wirewound types. The complete power supply is shown in the photo.

summary

I hope this article will encourage more hams to build, and not buy, their next piece of equipment. Once you take the initial step, designing and building ham gear can be fun. With transistors and multi-function

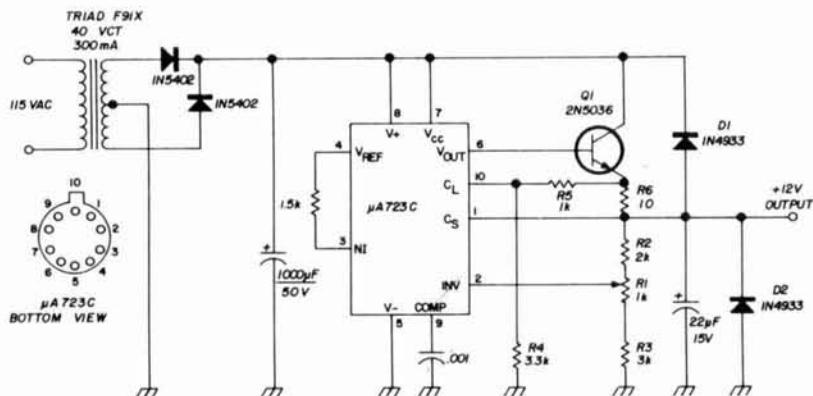


fig. 12. Regulated power supply uses a voltage-regulator IC in a foldback-current-limiting circuit. Output current is limited to 400 mA.

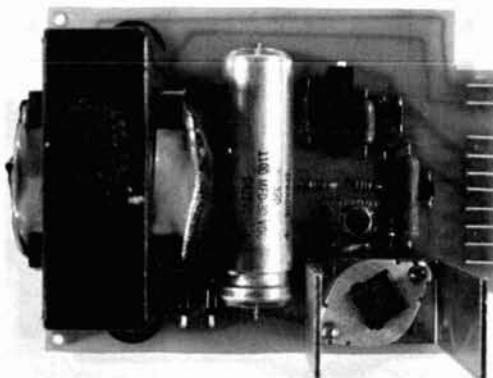
dissipated under normal full-load operation. This means that you have to use a larger heat sink to protect the transistor during long-duration short circuits.

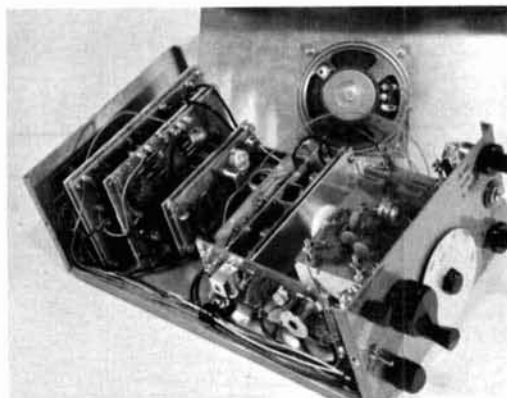
However, in the power supply in fig. 12 the current through Q1, when the output is short circuited, is only 85 mA. In normal operation the output voltage remains at 12 volts until the output current reaches 400 mA. If the load resistance decreases further (load current increases) the voltage and current decrease to their short-circuit values of 0 volts and 85 mA respectively; this is called foldback current limiting. Resistors R4, R5 and R6 set the current knee and short-circuit current. The μ A723 data sheet provides a formula for selecting resistor values for different applications.

Diodes D1 and D2 are protective diodes that are useful in any power supply¹⁸. For stable power supply operation, resistors R1,

integrated circuits, it is possible to come up with circuits that would have been impractical a few years ago. And in the future we can look forward to even more exciting new devices.

Power supply uses feedback current limiting.



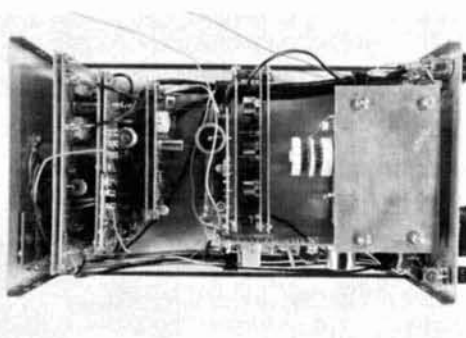


Internal construction of the receiver. Board positions from the rear as follows: bfo, product detector and audio stage; a-m i-f strip and filters, and ssb agc; 25-kHz calibrator; audio output; high-pass filter; and vfo. The mixer board is mounted on the side of the tuning capacitor.

Bob Hirschfeld, W6DNS, who designed the LM372, has stated that, "future developments in the communications IC area are

going to raise a few more eyebrows."¹⁹ Engineers at Fairchild Semiconductor make similar statements: "Second generation linear circuits will make their biggest impact in the field of communications . . . An entire family of circuits is under development for manpack mobile, and ground-based communication system."²⁰

I wish to thank Don Coppage for taking the photographs of the complete receiver.



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ham radio



NCX-1000 1 Kw Solid-State Transceiver (80 thru 10 Meters)

Here's a transceiver designed for the amateur who would rather spend his hard-earned radio dollar on performance than frills. The NCX-1000 is built to meet the demands of the operator who needs and desires a high performance SSB-AM-CW-FSK rig with solid-state dependability and plenty of power. Add to this the convenience of having your transmitter (including linear amplifier), receiver, power supply, and monitor speaker in a single, compact, smartly styled 59 pound package.

So let's look at the NCX-1000, starting with the double-conversion, solid state receiver. After the received signal is processed by a double-tuned preselector, a stage of RF amplification, and another preselector, it is applied to the first mixer for conversion to the first IF frequency. The first IF contains passband filters and a stage of amplification. A second mixer then converts the signal to the second IF frequency for additional processing by a 6-pole crystal-lattice filter and four IF stages. Finally, the signal is detected and amplified by four audio stages. The unparalleled high dynamic range lets you tune in weak stations surrounded by strong interfering signals. The result? High performance for SSB, AM, CW, and FSK. Sensitivity of 0.5 EMF microvolt (for a 10 db S+N/N ratio).

In the transmitter you'll find three stages of speech amplification followed by a balanced modulator, a crystal-lattice filter, a filter amplifier, and an IF speech processor (clipper). A mixer converts the signal to a first IF frequency for processing by two crystal passband filters, and two IF amplifiers. A second mixer converts the signal to the transmitting frequency where it is amplified in five RF stages before it gets to the grid of the 6BM6 driver. Final power amplification takes place in a forced-air-cooled 8122 ceramic tetrode which feeds the antenna through a pi network. Other features? You bet! Grid block keying for CW. Complete metering. Amplified automatic level control (AALC).

So here's a package that can give you 1000 watts PEP input on 80 through 10 meters, 1000 watts on CW, and 500 watts for AM and FSK. The speech processor lets you double your SSB average power output with minimum distortion. No frills with the NCX-1000. Just top performance.

Write for complete details.

 **NATIONAL RADIO COMPANY, INC.**
NRCI

111 Washington Street, Melrose, Mass. 02176
617-662-7700

low-band converted-vee antenna

This trapped antenna
provides low swr
operation on
40, 75 and 80 meters—
great for 5BDXCC

With the new 5-band DXCC award, interest in 40 and 80 meter operation has vastly increased. A number of W/K stations have completed, and many others are well on their way, to making the required contacts with one hundred countries on each of these bands. One could hardly avoid becoming intrigued with this challenge. Since my receiver and transmitter were already capable of covering these bands, my efforts turned toward a suitable antenna system.

dual-band inverted vee

With a central mast on my property and little chance of erecting other high poles the best compromise antenna appeared to be a combination 80- and 40-meter inverted vee patterned after the dipole described by Neil Handel, W1IR.¹ The 80 and 40 meter elements were separated with 1/4 x 6 inch wooden-dowel spacers simmered in a high-melting-point wax, as W1IR had done, for weather protection.

Since I operated for long periods of time on either cw or ssb I tuned the long legs of the inverted vee to 3.8 MHz for ssb operation and made provisions for connecting across egg insulators with shorting devices to lengthen each leg for 3.5 MHz cw operation. That way a relay and its associated wiring was avoided.

Clip wires could be used for shorting devices; however, they suffer several disadvantages. First, they can be inadvertently pulled off by branches or other physical obstructions. Second, it is possible that the clips may make poor electrical contact because they're connected onto a corroded spot on one of the wires. My solution was to use a shorted 83-1SP plug inserted into a receptacle soldered across an egg insulator.

The first combination antenna I used

Bob Polansky, W6JKR, 1024 Green Lane, La Canada, California 91011

is shown in **fig. 1**. The apex of this inverted vee was 55 feet above ground and the included angle between the antenna legs was approximately 120°. Length l_1 was chosen for the best compromise swr over the 7 MHz band, favoring the cw end; l_2 was chosen for the best compromise swr in the 3.8 MHz area, also favoring the lower ssb frequency with the shorting plugs removed; l_3 was chosen for the best compromise swr in the 3.5 MHz area again favoring the lower cw frequency with the shorting plugs in place. Note that these lengths will vary somewhat as a function of antenna apex heights, end heights and included angle.

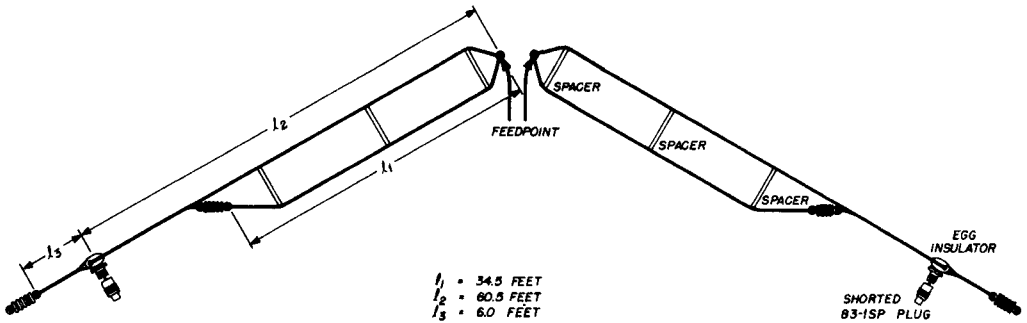


fig. 1. Initial 80-, 75- and 40-meter antenna system.

No interaction was noted between the 40- and 80-meter elements of this antenna system while experimenting with the lengths of each. The indicated swr for 40-meter operation was always less than 2:1 while on 80 meters it was possible to cover 300 kHz with an swr less than 2:1.

I soon found myself making numerous trips to the roof to remove and install the shorting plugs as exotic DX stations kept appearing in the 80 meter sub-band for which I was **not** set up. Certainly, I thought to myself, another solution, one not needing relays, clip wires, or other physical changes to the antenna system was possible.

converted vee

For planning purposes, operation was desired at an swr of less than 2:1 between 3.5 and 3.6 MHz, and between 3.8 and 4.0

MHz. The frequencies between 3.6 and 3.8 MHz were of no concern for transmitting purposes. With this in mind, my thoughts immediately turned toward a parallel LC trapped antenna scheme. Would it be possible to develop, with reasonably sized components, a trap with high enough Q to be effective at 3.8 MHz and not at 3.5 MHz? If it were, the wire inside the trap (toward the center of the antenna) would load well in the 3.8 MHz region, while the inductive reactance added by the trap itself plus a short length of wire outside the trap might load in the 3.5 MHz region. The idea sounded crazy enough to work.

trap construction

Recent issues of the ARRL Radio Amateur's Handbook discuss the construction of such traps. Basically, it involves the following:

1. Two loops of the antenna wire you intend to use are passed through an egg insulator in the normal manner. Both ends are then wrapped, cut off close to wrap, and soldered, leaving the insulator with two loops of wire.
2. The tuning capacitor is soldered across the two independent loops.
3. A larger than necessary inductor is soldered across the insulator-capacitor combination.
4. The entire assembly is grid dipped, and the inductance trimmed until the dip occurs at the proper frequency.

5. The LC circuit is then disassembled, the actual antenna wire wrapped around the egg insulator as before, and the trap rebuilt and soldered.

The traps I built used 50 pF Centralab ceramic transmitting capacitors, part number 850S-50Z,* which are rated at 7500 Vdc. A greater safety margin could be obtained by using 15,000 Vdc capacitors, but the cost would have increased by a factor of more than three.

For the inductor, 2½-inch OD lucite tubing 5 inches long was used as a coil form. The form was slotted on a lathe at 10 turns per inch. To resonate the

from WRL. Either of two coils would suffice: the Air Dux 2010T (2½-inch diameter, 10 turns per inch number 16) or the Air Dux 2410T (3-inch diameter, 10 turns per inch number 14). These coils, when split in half, should provide more than enough inductance to build two traps.

A note of caution is in order here. When trimming the coils, monitor the grid-dip oscillator output on a well calibrated receiver—don't trust the oscillator's calibration. The grid-dip oscillator dial I used was more than 100 kHz out of calibration.

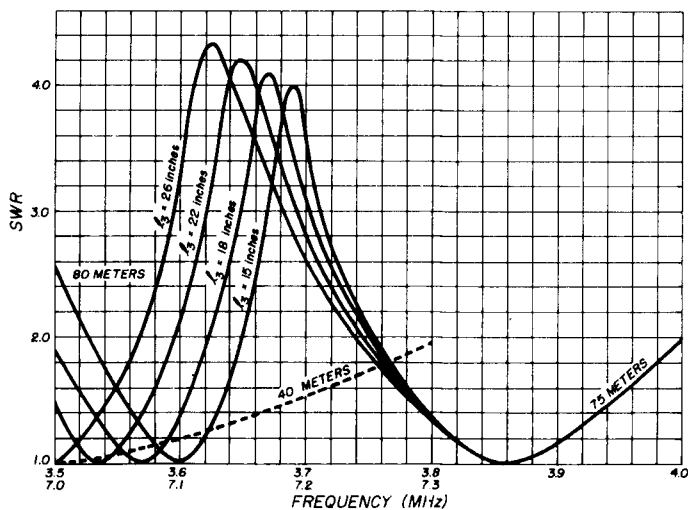


fig. 2. Standing-wave ratio performance of the converted-vee antenna.

traps at 3.805 MHz, the design frequency, the required inductance was 33.7 microhenries. This was fabricated by winding 33 turns of number 14 wire on the pre-slotted lucite form. The LC combination was then fine-tuned to the proper frequency by trimming the inductance and observing the results on a well calibrated grid dip meter. The final coil ended up being 30 turns.

Another reasonable approach is to buy a 10 inch Air Dux coil, which is available

* The 50-pF Centralab 850S-50Z ceramic transmitting capacitors are available from Allied Electronics, 100 N. Western Avenue, Chicago, Illinois 60680. Order part number 43D1101, \$2.70 each plus shipping.

weatherproofing

Since hollow lucite forms were used for my traps, end caps were fashioned on a lathe and cemented into the hollow ends of the forms to keep excessive moisture out of the traps. Drain holes were drilled in the low end of the traps to let trapped moisture drain out.

The traps have not yet been subjected to the rainy season, so I don't know how the wire wrapped around the outside of the forms will hold up. If Air Dux coils are used, a soft, flexible plastic container of some type should be used around the traps.

performance

With the traps installed in both legs of the antenna in place of the shorting plugs various lengths of l_3 were tried. Success! Two nulls in swr were noted; one in the 3.8 MHz region and one around 3.5 MHz. Changing l_3 had little effect on the 3.8 MHz swr characteristics; however, it did move the swr null across the 3.5 to 3.6 MHz region, as shown in **fig. 2**. An l_3 of 18 inches produced an swr of less than 2:1 for a range of frequencies from 3.5 to 3.64 MHz.

The experimenter may wish to modify the characteristics of either the 7, 3.8, or

tuned on the bench to 3.805 MHz. When checked, installed in the antenna, their resonant frequency had lowered to 3.760 MHz. This was expected, due to the added inductance of the antenna; however, the swr null at 3.860 MHz came as a pleasant, but unexpected surprise.

The finished converted-vee antenna is shown in **fig. 3**. Note that the apparent capacitor value in each trap is 52 pF (50 pF from the capacitor itself and 2 pF from the antenna wire wrapped around the egg insulator). The antenna is fed with RG-8A/U coax.

No balun is used nor was one tried.

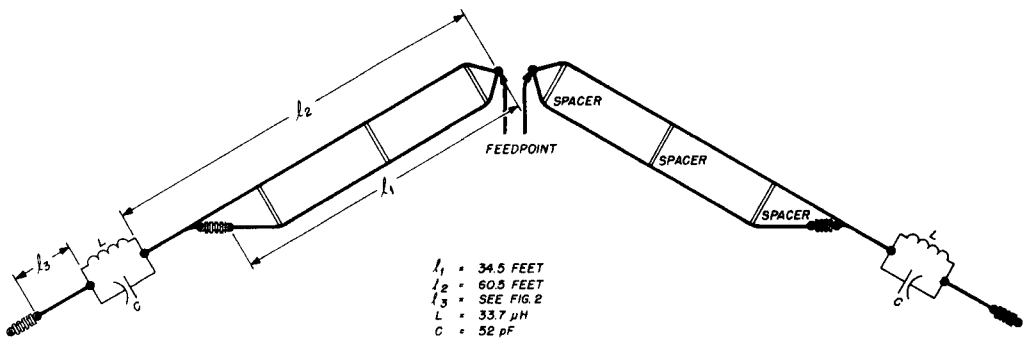


fig. 3. Converted-vee antenna system provides low swr operation on 80, 75 and 40 meters.

3.5 MHz portions of the antenna system. Since no interaction between the 80 and 40 meter elements was observed, each can be trimmed independently. Shortening l_1 to 33 feet moved the swr null to 7.3 MHz. Intermediate lengths will produce swr nulls at other frequencies in the 7 MHz band.

For the chosen 3.8 MHz parameters, the 3.5 to 3.7 MHz characteristics can be modified by selecting different lengths of l_3 , as indicated in **fig. 2**. If a change in the 3.8 MHz characteristic is desired, both l_2 and the trap frequency will have to be changed simultaneously. These changes will undoubtedly modify the length l_3 required to achieve the same 3.5 MHz characteristic as before. No actual data were obtained on this.

One interesting observation should be noted here. The traps in my antenna were

The antenna readily accepts the full output of my SB-200 linear amplifier for all swr readings of less than 2.6 to 1, and has performed very competitively on the air.

summary

This is the first time to my knowledge that parallel traps have been used to permit operation on two "in-band" frequencies. It is presumed that these results are applicable to horizontal antennas on 3.5 to 4.0 MHz although no data are on hand to illustrate this.

I wish to thank K6KA and W6EJJ for their encouragement, suggestions and assistance which contributed to the success of this venture.

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ham radio

trapezoidal monitor scope for single sideband

One of the advantages of single sideband is a reduction in interference because channel width is reduced by one-half. However, there seems to be more interference these days than when a-m was popular. Much of this can be attributed to increased activity. But I believe a large percentage of unnecessary interference from ssb equipment is the result of distortion the operator isn't aware of.

If a monitor scope is used in the conventional manner to display an ssb signal, the "Christmas tree" pattern will readily show distortion caused by severe flat-topping. However, a small amount of flat-topping, which may occur in the ssb exciter between the first mixer input and succeeding circuits, is virtually impossible to detect on the familiar "Christmas tree" scope pattern.

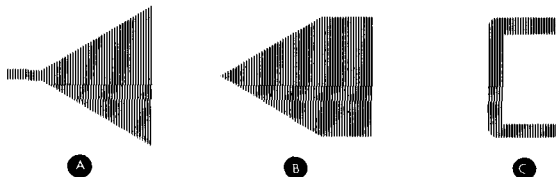
A good way to resolve this problem is to continuously monitor a trapezoidal pattern of the transmitter's performance. This article presents a simple circuit that can be used with a commercially manufactured monitor scope or with a home-built monitor using a small-diameter cathode-ray tube. When properly connected between your ssb transmitter and monitor, the circuit will allow a trapezoid pattern to be displayed. Such a pattern will respond to the slightest amount of flat-topping caused by nonlinearity in the transmitter.

Royden C. Golding, VE3CUS, 69 Gordon Road, Willowdale, Ontario, Canada

An oscilloscope will show the wave envelope of an a-m or ssb transmitter if (a) a sample of the modulated signal is applied to the scope's vertical deflection plates, and (b) the scope's horizontal deflection plates are driven by a signal from a time-base generator. The time-base signal, or sweep, is usually generated inside the scope. If the scope doesn't have such a circuit, the 60-Hz line frequency can be used. The resulting scope pattern is useful for checking modulation percentage. It will respond to extreme nonlinearities, but it doesn't tell you much about what's happening in low-level stages. A trapezoidal pattern is necessary for this.

The trapezoidal pattern is actually a graphical representation of the transmitter's modulation characteristic. Any nonlinearity, however slight, becomes immediately apparent as the pattern shape departs from a true trapezoid. Typical patterns for a-m and ssb signals with over

fig. 1. Trapezoidal scope patterns. An a-m signal with over modulation is shown at A; ssb signal with flat-topping, B. C represents a saturated transistor or faulty diode in the monitor circuits.



modulation and flat-topping are shown in **figs. 1A** and **1B**. (The pattern in **fig. 1C** is caused by problems in the instrumentations circuit, which are discussed later.)

A trapezoid may be displayed on a scope by applying a sample of the transmitter's modulated output to the scope's vertical plates and applying a sample of the audio modulating signal to the horizontal plates. The signal applied to the scope's horizontal plates must have no rf

ation, and we wish to monitor **all** linear stages from this point on.

The second pick-off point, where the transmitter's modulated output is applied to the scope's vertical plates, can be at the exciter's output or at the output of a linear final amplifier. If a switching circuit is used, as shown in **fig. 2**, you can monitor the entire system. However, the important thing to remember is that the pick-off point for the accessory circuit should be at the input to the **first mixer**.

distortion in the audio circuits

If there is distortion in your ssb signal caused by the speech amplifier or balanced modulator, a more sophisticated circuit than that described here will be required to isolate the problem. However, if such distortion should occur, the result at the receiving end of your transmission is garbled speech, **not** spurious radiation caused by flat-topping. Splatter, caused by nonlinearities in low-level rf circuits, is what we're trying to monitor with a trapezoidal pattern on the scope.

preliminary checks

The first thing to do is to check your exciter and decide just how you're going to adapt the circuit. The input to the vertical plates of the scope is no real problem. It can be coupled from the exciter (or linear amplifier) output through a capacitor, using a convenient length of coaxial cable. Use a small link at the transmitter. The link can be adjusted to give an appropriate amount of signal.

The input to the scope's horizontal plates is applied through the circuit of **fig. 3**. Bear in mind that the output signal from this circuit has the same wave shape (less the rf component) as the signal applied to the scope's vertical plates.

Before starting construction, check your exciter to determine if you have enough spare drive for the monitor circuit. The signal should be picked off as soon as possible after the unwanted sideband has been eliminated. In some exciters this is the "first mixer" or "first i-f amplifier," or possibly the "balanced mixer." Only by

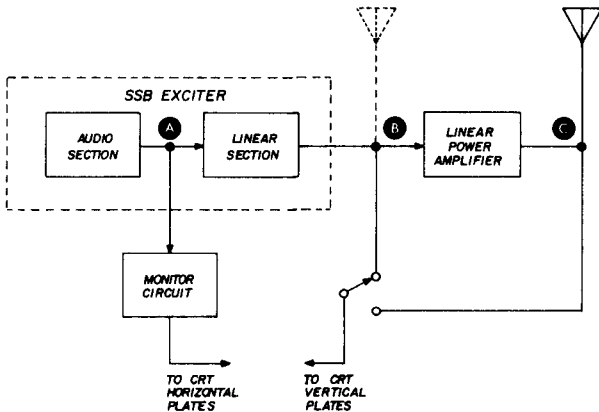


fig. 2. Block diagram showing low- and high-level inputs to oscilloscope. Low-level input, point A, is taken from grid tap on first mixer. High-level input may be taken from exciter output, point B, or from output of linear amplifier, point C.

component. Therefore, the modulating signal from your ssb exciter must be rectified before it's applied to the scope. This is the basis of the monitor circuit to be described. This circuit consists of a simple rf amplifier followed by a diode detector that drives an audio amplifier to provide sufficient voltage for the monitor scope's horizontal plates.

pick-off points

The place where the monitor circuit is inserted into the ssb transmitter is important. The block diagram of **fig. 2** will help clarify this. The input signal to the monitor circuit is taken from the exciter's **first mixer**. In most ssb exciters, this is the first stage that could produce nonlinear oper-

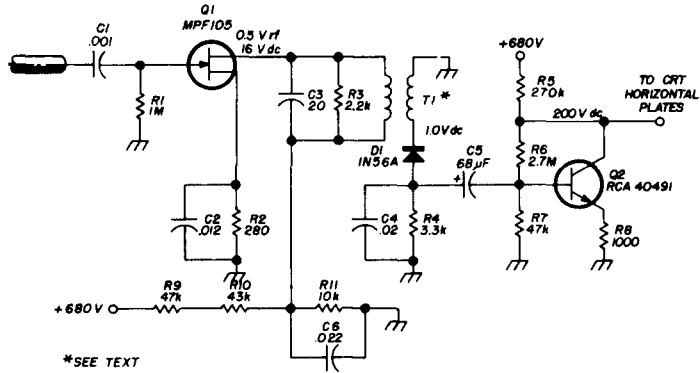
monitoring the signal from the grid of this tube to the output can we be sure of including all linear circuits.

Now decide where to mount the indicating scope tube (peeking out through a hole in the exciter front panel is an ideal arrangement). Measure the distance (this can often be reduced to four

construction

The rf transformer should be tackled first (fig. 3). The design will depend upon the carrier frequency of your rig. The transformer needs a bandwidth of perhaps 3000 Hz above and below the carrier frequency. If your carrier is 455 kHz, a suitable i-f transformer can be found in

fig. 3. Simple three-stage monitor circuit for driving horizontal plates of scope to obtain trapezoidal pattern. Power is taken from exciter supply.



or five inches) from the grid of the first mixer to the nearest point in the set where you can mount the circuit board. Cut a piece of coax to this length, then ground the grid of the first mixer through the coax, a .01 μ F ceramic capacitor, and a 1-megohm resistor (fig. 4).

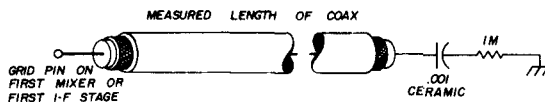
Now try the set under operating conditions. If the mixer grid is tuned, you will have upset the tuning. Retune the circuit until full output is again obtained. This proves that the set will take the slight drain needed for the monitor circuit and still operate. If the mixer grid is not tuned, probably no effect will be noticed. But if output is reduced, some means of increasing drive at the mixer grid must be found to compensate for the loss. If it is a balanced mixer circuit, try placing equal capacitance and resistance on the second grid to keep the two halves balanced.

the surplus shops. A 9-MHz carrier is also fairly common. A successful 8-MHz mc coil was made by adding a few turns to the primary of a 9-MHz i-f transformer until it resonated at 8-MHz with a 20-pF ceramic capacitor and a 2200-ohm resistor across it. The secondary coil should have more inductance than the primary coil to give a voltage step-up. A gain of $1\frac{1}{2}$ to 2 is adequate.

We now have some inductance in the circuit. This is desirable, since capacitance introduces phase shift and consequent distortion in the scope pattern. At all points we must watch linearity in the design. Our whole purpose is to demonstrate linearity on the screen; thus any distortion introduced in the monitor circuit would give a false indication.

An input rf stage is needed as well as an audio amplifier to follow the demodulating diode.

fig. 4. Test circuit to determine drive capability of exciter. It's used once and discarded.



We need a high impedance input for the MPF105 jfet which is provided by R1. For the output we need a high resistance; this is provided by the tuned primary transformer circuit. The diode is quite critical, particularly as to temperature. Out of a large number tried, the one selected was a 1N56A.

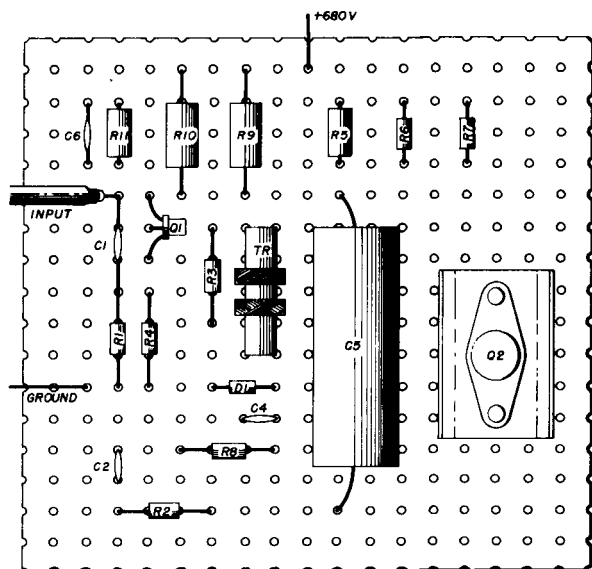


fig. 5. Arrangement of components for the monitor.

The coupling capacitor feeding the signal to the power transistor must be large to keep down reactance and phase shift.

The output transistor operates at a rather high voltage.* Audio output under the conditions described should be too high rather than too low. Rf voltages at certain parts of the circuit are given in fig. 3. These were measured with a Heathkit vtvm. A series of "aah's," spoken close to the microphone, will produce the values shown.

* The author used an RCA 40264 transistor for the audio amplifier (also shown in the circuit-board photo). This device is no longer produced by RCA. However, the RCA type 40491 is an acceptable substitute. Its electrical characteristics are almost identical to those of the 40264. Also, the 40491 has a heat radiator, whereas the 40264 does not. The 40264 will fit nicely on the circuit board. It costs about 85c and is available from Allied Radio. Editor.

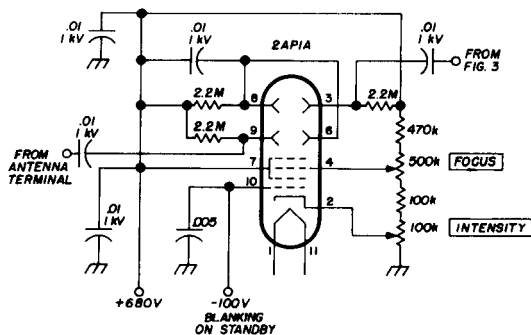
If too much voltage is obtained, decrease R4's value until a suitable pattern size is obtained. An unusual scope pattern obtained at one time is shown in fig. 1C; this was the result of a faulty diode.

A suggested component layout for the monitor circuit is shown in fig. 5. The Vector board may be mounted inside your exciter, as discussed previously. All signal leads should be coax cable (such as RG-58/U), and the shield should be grounded at each end.

My original scope circuit is shown in fig. 6. I've used this circuit, so I'm certain it will work. The scope circuit shown in the 1969 edition of the ARRL Handbook, however, should be equally satisfactory. Note that the voltages in fig. 6 are lower than those shown in the Handbook circuit. These voltages were available in my transmitter power supply, so I used them.

In fig. 6, the 2AP1A grid is biased to blank the spot when the transmitter is on standby. You should be able to pick up -100 volts in your ssb exciter for this purpose.

fig. 6. Monitor scope circuit using transmitter high-voltage supply. Any good scope circuit could be used.



If you wish to use a commercially manufactured monitor, the amplifiers will have to be disconnected and the signals fed directly to the scope plates.

I think you'll find the circuits described here will provide a good indicator to show when your rig is flat-topping. I encourage you to use it all the time.


ham radio



graphical solution

of impedance- matching problems

Using
simple geometry,
these methods
allow you
to design
a variety
of networks



One of the most common problems in radio circuits is matching one impedance to another. The problem might be that of matching a transmitter output stage to a resistive load, or the load may have a reactive component, as is usually the case when attempting to transfer power to an antenna.

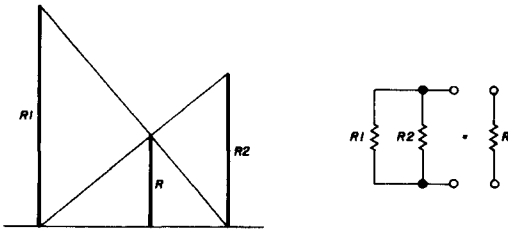
Many articles have been written covering the mathematics of this problem and also the application of the Smith chart.^{1,2,3} Impedance-matching problems can be solved readily with sufficient accuracy for practical purposes with no more equipment than a straight edge, compass and graph paper. The graphical method lends itself to multiple-component networks involving complex impedances, without resorting to trigonometry or complex algebra. It allows a visual choice of constants and shows forbidden approaches in choosing impedance paths.

The method presented in this article will allow you to solve most impedance problems encountered in amateur work. The geometric principles are easy to follow, and you'll need to make only a few simple computations. Rules are given for constructing the diagrams. Typical examples and solutions are shown. The examples are presented without mathematical proof, however. For those who wish to pursue the classical approach, some excellent material will be found in references 4, 5 and 6.

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a starting point

First consider the familiar methods known as the "leaning ladder" diagram for determining the resultant of two resistors or reactances in parallel (fig. 1). Two perpendicular lines with lengths proportional to the two resistors or reactances are erected with arbitrary separation from a common baseline.



1. The "leaning ladder" diagram for finding the resultant of two resistances or reactances in parallel.

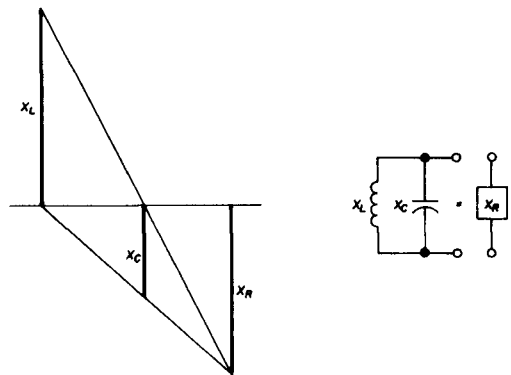
Lines are then drawn from the top of each perpendicular to the base of the other. A third perpendicular is now drawn from the intersection of these lines to the baseline. The length of this new perpendicular is proportional to the combined resistance or reactance of the two parallel elements.

What happens, however, when two reactances of opposite sign are to be evaluated? The same procedure is followed as before, except that the perpendicular lines representing the reactances will be located on opposite sides of the baseline (fig. 2). Again we connect the end of each perpendicular to the base of the other, extending the lines until they intersect. The length of a perpendicular from this point of intersection to the baseline represents the combined reactance of the two paralleled elements. The side of the baseline where the intersection takes place determines whether the resultant, X_R , is inductive or capacitive.

Now suppose a reactance is to be paralleled with a resistance. How do you determine the impedance of such a combination? Semicircles are constructed upon rectangular coordinates, with diameters proportional

to the paralleled resistance and reactance, intersecting at point A (fig. 3). A line, O-A, from the origin to the point of intersection will be proportional to the impedance of the combination. The projections of this point of intersection upon the resistive and reactive axes will then be proportional to the resistance, R_S , and reactance, X_S , respectively, which make up the series equivalent of the parallel combination.

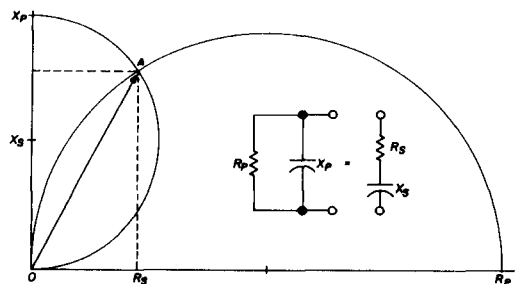
Because an angle inscribed in a semicircle is always a right angle, it is easily shown that the point of intersection, A, lies on a straight line connecting the ends of the two diameters. This construction leads to a well-known diagram frequently used to



2. Diagram for finding resultant impedance of two reactances of opposite sign.

solve L networks, (fig. 4). An L network is merely a transformation from a parallel resonant circuit, seen looking in at Z1, to a series resonant circuit, seen looking in at Z2.

3. Geometry for solving parallel-to-series transformation.



rules for construction

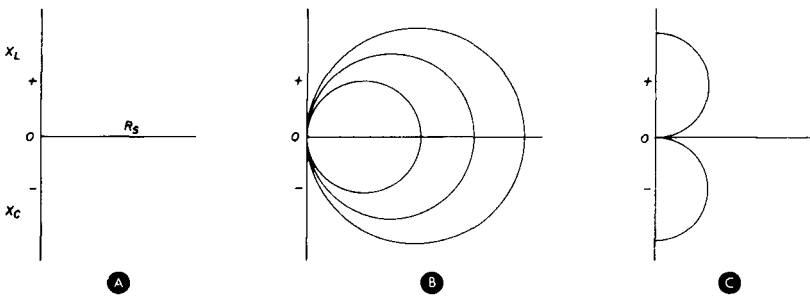
By combining these diagrams, it's possible to solve a variety of matching-network problems. The geometry of **fig. 5** is the basis of solving all problems using this method. General rules for using the method are:

1. Adding a series of reactances moves the impedance on a vertical line: up for inductive and down for capacitive reactance.
2. Adding a parallel reactance moves the impedance along a circle with its center on

not permissible to use a path passing through the origin of coordinates.

The method permits rapid comparison of different network designs without a knowledge of complex algebra, and a clear picture is given of what happens when parameters are modified.

We'll begin with the pi network since this is one of the most-used circuits in amateur work. Other circuits will then be described, which will provide a foundation for solving



5. Basic geometry for graphical solution of impedance problems. Series resistance is plotted along the horizontal axis and series reactance on the vertical axis, as at (A). Parallel resistance and parallel reactance circles are constructed as in (B) and (C) respectively.

the horizontal axis. It rotates clockwise for capacitive and counter clockwise for inductive reactance.

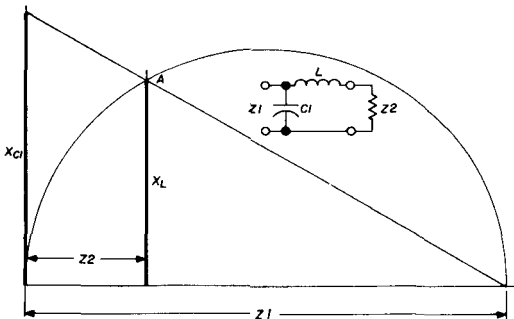
3. When choosing impedance paths, it is

most impedance-matching problems. Some numerical examples are then given to show step-by-step procedures.

the pi network

The pi network can be considered as two cascaded L networks, designed to transform both input and output impedances to a common internal transfer impedance, which must be lower than either terminal impedance. This internal transfer impedance determines the network Q, a fact that becomes apparent from a consideration of the design diagram (**fig. 6**).

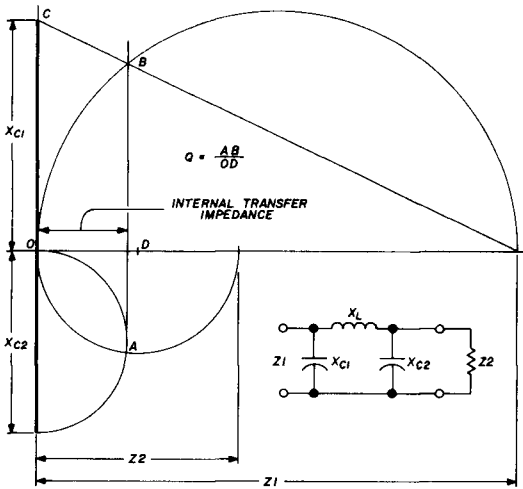
To design a pi network, begin at the origin of a set of rectangular coordinates, and construct a semicircle above the horizontal axis, with diameter proportional to Z_1 . (Z_1 is the greater of the two terminal impedances.) Similarly, from the origin con-



4. The L network diagram. Another example of parallel-to-series transformation.

struct a second semicircle below the axis. Its diameter is proportional to Z_2 , the lesser of the two terminal impedances.

Because an infinite number of solutions exist to a pi-network problem when terminal impedances are specified, an assumption must be made for one of the three reactances. This is necessary to establish the internal transfer impedance. There are certain advantages if the reactance of the output capacitor, C_2 , is made equal to the load resistance, Z_2 . However, network Q require-



6. The pi network diagram. Circuit Q is determined by the internal transfer impedance.

ments frequently dictate a lower value as discussed later.

The assumed reactance, X_{C2} , of the output capacitor becomes the diameter of a third semicircle, beginning at the origin and constructed downward below the horizontal axis. The point of intersection between this and the Z_2 semicircle is point A. From this point a vertical line is drawn to intersect the original Z_1 semicircle at point B. The length of the line segment, AB, represents the required reactance of X_L .

A straight line is now drawn from the extreme end of the Z_1 diameter through point B, intersecting the vertical axis at point C.

Line OC will then be proportional to X_{C1} , the reactance of the required input capacitor.

The intersection of inductive reactance line AB with the horizontal axis is point D. The significance of this point is that line segment OD represents the internal transfer impedance of the network. The Q of the network, when driven by a current generator such as a screen-grid tube or a transistor, will be equal to the inductive reactance, AB, divided by the internal transfer impedance, OD. The Q will also be equal to Z_1/X_{C1} plus Z_2/X_{C2} , which can be proven identical.

When driven by a resistive source, such as a triode, the network is loaded from both ends, and the effective Q may be cut in half.

the tee network

Although the T network is not as well known as the pi network, it is a very useful circuit and is quickly solved graphically. With the T network, we may assume the internal transfer impedance as equal to or greater than the sum of the terminal impedances Z_1 and Z_2 , usually by a factor or two or more. The graphical design procedure, with reference to fig. 7 is as follows:

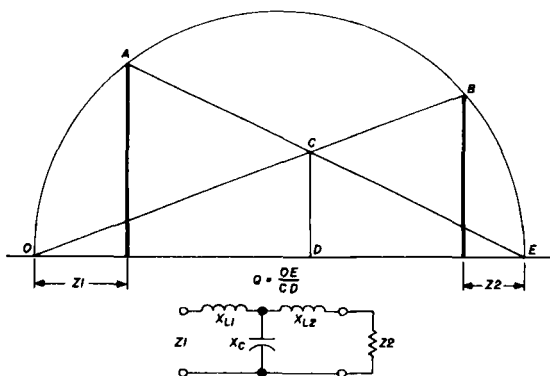
Construct a semicircle with horizontal diameter **greater** than the sum of the terminal impedances. Mark off, from opposite ends of the diameter, line segments proportional to the two terminal impedances. From these two points erect perpendiculars to intersect the semicircle at points A and B respectively. Connect points A and B to the remote ends of the diameter, intersecting each other at C. A perpendicular, CD, to the diameter will be proportional to the reactance of the capacitor, C. The Q of this network, as driven by a current generator, will be equal to the diameter of the semi-circle divided by the line segment CD. The sum of X_{L1}/Z_1 plus X_{L2}/Z_2 will give an identical result.

Although the derivation of this diagram may seem obscure, if perpendiculars are erected at the ends of the diameter, and the slant lines extended to intersect these perpendiculars, we will have the two superimposed L-network diagrams. The line segments of these end perpendiculars will each represent a capacitive reactance correspond-

ing to one of the two cascaded L networks making up the complete T network. The extended slant lines can then be seen to represent the leaning-ladder diagram, with line CD being the result of both capacitive components in parallel. Therefore all construction exterior to the semicircle will be redundant and can be omitted.

If the semicircle is constructed so that its diameter is equal to the sum of the two terminal impedances, all reactances will be of the same magnitude, differing only in

7. Solving the T network. The internal transfer impedance is equal to or greater than $Z_1 + Z_2$ by a factor of two.



sign, and will be equal to the geometric mean of the terminal impedances. The Q of such a network would be quite low, being equal to the sum of the two terminal impedances, divided by the square root of their product.

When the pi network is designed so that $Z_2 = X_{C2}$, excursions of Z_2 will have minimum effect on Z_1 . Resonance will be maintained by retuning X_{L1} . A network is possible whereby a two-to-one range of Z_2 (assumed purely resistive) will, in turn, cause Z_1 to vary from the target impedance by less than five percent.

Similarly, design of the T network so that $Z_1 = X_{L1}$ will permit Z_1 variations of the same magnitude, with the network output still presenting a match to the load (within the same limits). Resonance is maintained by retuning C_1 .

In either network the terminal impedance, Z_1 , is assumed the higher of the two. Al-

though Z_1 has been treated at the input end, either network is completely reciprocal.

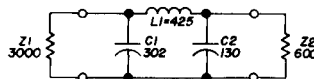
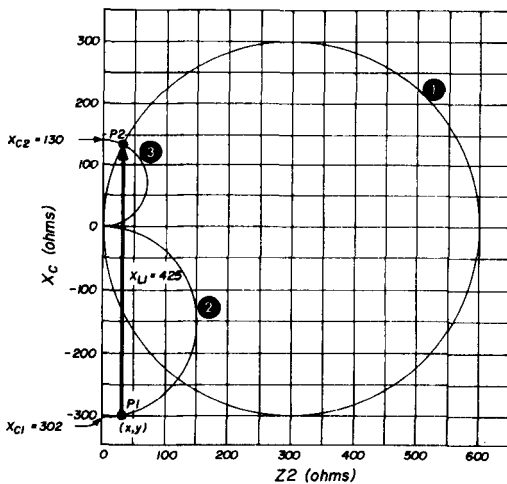
examples using pi networks

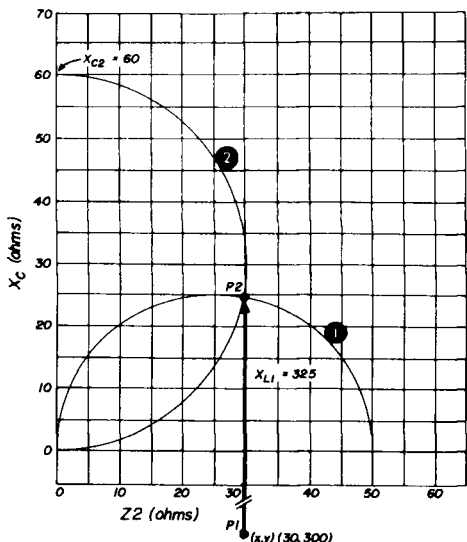
problem 1. Match $3000+j0$ ohms to $600+j0$ ohms with a pi network. In this case, $Q = 10$.

1. Draw a 600-ohm circle (1), **fig. 8**.
2. Calculate point (x, y) and plot:

$$y = \frac{R_1}{Q} = \frac{3000}{10} = 300.$$

8. Solution to problem 1: matching $3000+j0$ ohms to $600+j0$ ohms with a pi network. Arrows indicate impedance path.





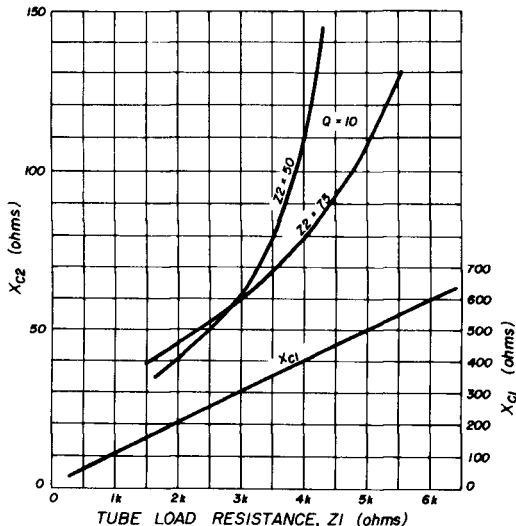
9. Solution to problem 2: matching $3000+j0$ ohms to $50+j0$ ohms with a pi network—a common problem in transferring tube output impedance to an antenna transmission line. Expanded scales for $R2=50$ ohms are shown at (A). At (B) the curves are limited to $R2=50$ or 75 ohms and $Q=10$.

$$x = \frac{R1}{Q^2} = \frac{3000}{100} = 30.$$

3. Erect a vertical line from point P1 (x, y) to intersect the 600-ohm circle at point P2. This is X_L to scale (425 ohms).
4. Draw circle (2). Its intercept on the vertical axis at 302 ohms is X_{C1} .
5. Draw circle (3). Its intercept on the vertical axis at 130 ohms is X_{C2} .
6. Solution: $L1 = 425$ ohms
 $C1 = 302$ ohms
 $C2 = 130$ ohms

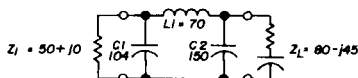
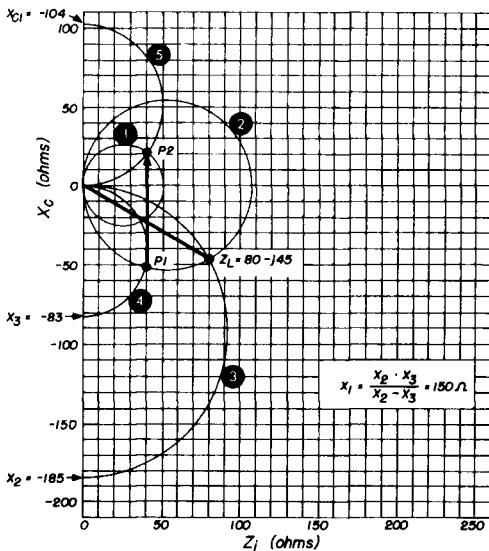
problem 2. This is the same as problem 1, except $Z2 = 50$ ohms (fig. 9).

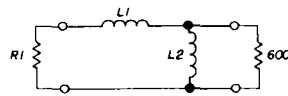
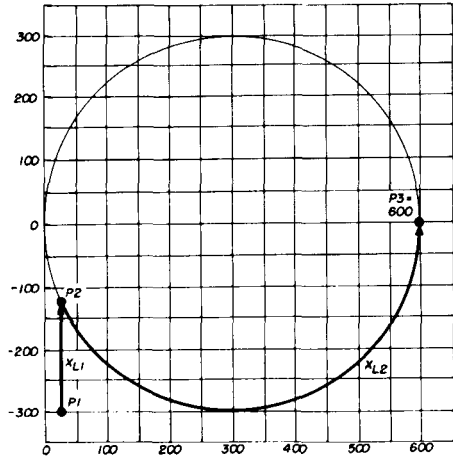
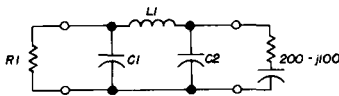
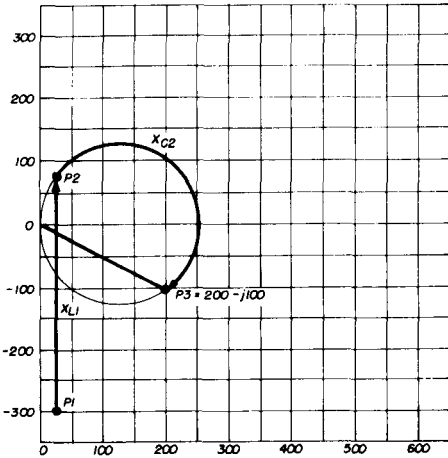
1. Draw a 50-ohm circle (1), fig. 9A.
2. Erect X_{L1} through $X = 30$ to intersect the 50-ohm circle at point P2. This scales to $y + 25$, or $X_{L1} = 325$ ohms.
3. Draw circle (2) through point P2. It will intersect the vertical axis at $X_{C2} = 60$ ohms.
4. Solution: $L1 = 325$ ohms
 $C1 = 302$ ohms
 $C2 = 60$ ohms



Some pi-network curves for common tube load resistance are shown in fig. 9B.

10. Solution to problem 3: matching an antenna load of $80-j45$ ohms to $50+j0$ ohms with a pi network. This has a three step impedance path: Z_L to P1 to P2 to Z_i .





11. Examples of correct impedance paths. Both show networks for matching typical power amplifier tube impedances to various loads. Note that the impedance paths must not pass through the origin of coordinates.

problem 3. Match an antenna load of $80-j45$ ohms to 50 ohms using a pi network (fig. 10).

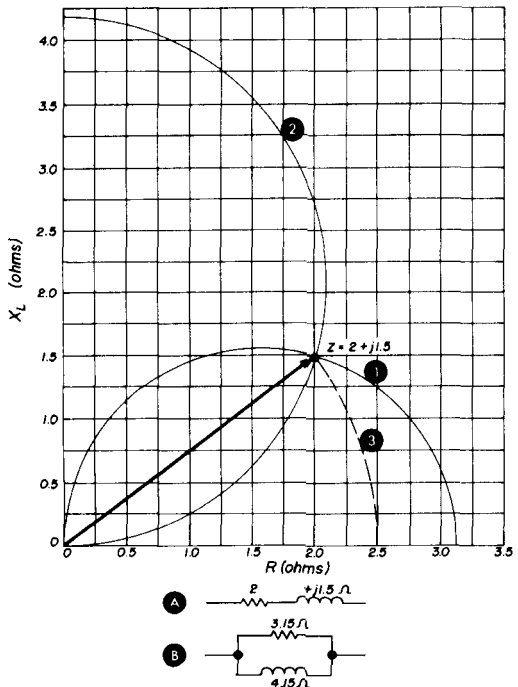
1. Construct a 50 -ohm circle (1).
2. Plot $Z_L = 80-j45$ ohms.
3. Construct circle (2) through Z_L .
4. By inspection the maximum value of X_T is about 75 ohms. Select a value of 70 ohms and fit it vertically as $P1$, $P2$ between circles (1) and (2).
5. Construct circle (3) through Z_L . It will intersect the vertical axis at -185 ohms ($X2$).
6. Construct circle (4) through $P1$. It will intersect the vertical axis at -83 ohms ($X3$).

$$\begin{aligned}
 X1 &= \frac{X2 \cdot X3}{X2 - X3} \\
 &= \frac{(-185)(-83)}{(-185) - (-83)} = \frac{-185 \cdot 83}{102} \\
 &= 150 \text{ ohms.}
 \end{aligned}$$

This is capacitive reactance added by moving from Z_L to $P1$.

choice of impedance paths

Recall that the internal transfer impedance must be lower than either terminal im-



12. Solution of series-to-parallel transformation. The resultant impedance is 2.5 ohms.

pedance. The internal transfer impedance determines the Q of the pi network. From **fig. 6**, line segment OD determines this parameter. Therefore, from the rules of construction for graphical solution to these problems, it is not permissible to choose an impedance path through the origin of coordinates. Examples of correct impedance paths are shown in **fig. 11**. Here, these show transformation between typical tube output impedances and various load impedances. Note that the paths do not pass through the origin. While a 600-ohm terminal impedance is not too common in most rf circuits these days, the example does indicate the principles to be followed when designing these networks.

solving series and L networks

problem 1. Given the series circuit of **fig. 12A**, find the equivalent parallel circuit.

1. Plot the impedance vector $Z = 2 + j1.5$.
2. Construct circle (1) with its center on the

horizontal axis, which passes through the origin and Z as shown. It will intersect the horizontal axis at 3.15 ohms resistance.

3. Construct circle (2) with its center on the vertical axis, which passes through the origin and Z. It will intersect the vertical axis at 4.15 ohms inductive reactance. The equivalent parallel circuit is shown in **fig. 12B**.
4. Solution. Scaling the Z vector gives an impedance of 2.5 ohms (3).

problem 2. In the network of **fig. 13**, it is desired to find X_L , X_C , L, and C for a frequency of 3.9 MHz.

1. Construct circles (1) and (2) through 50 ohms and 75 ohms as shown.
2. Construct line P1-P2, which is X_L series and scales 35 ohms.
3. Construct circle (3) through P1. It will intersect the vertical axis at -105 ohms. This is X_C parallel capacitive reactance obtained in moving clockwise from 75 ohms along circle (2) to P1, which is directly below P2, the 50-ohm point.

4. Solution.

$$L = \frac{X_L}{2\pi f} = \frac{35}{2\pi \times 3.9} = 1.43 \mu\text{H}$$

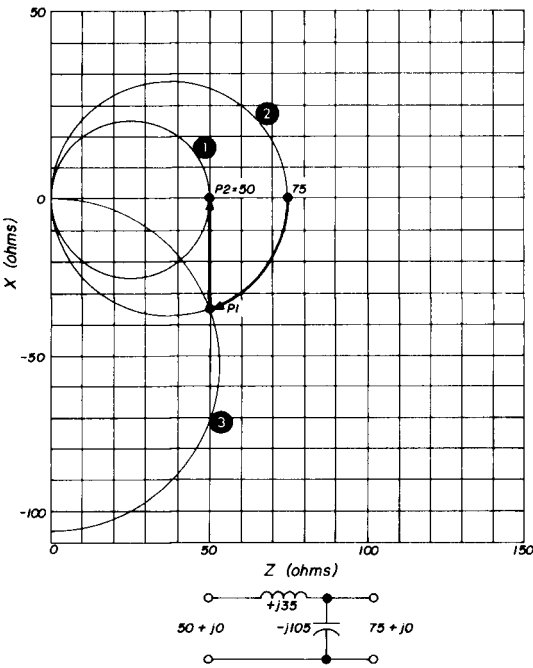
$$C = \frac{10^6}{2\pi f X_C} = \frac{10^6}{2\pi \times 3.9 \times 105} = 386 \text{ pF}$$

$$X_L = 35 \text{ ohms}$$

$$X_C = 105 \text{ ohms}$$

problem 3. Match $50 + j0$ ohm to $Z_L = 125 - j72$ ohms, a complex load (**fig. 14**).

1. Construct a 50-ohm circle (1).
2. Plot $Z_L = 125 - j72$.
3. Construct circle (2) through Z_L .
4. Construct a vertical line from P_2 to P_1 . This is the series X_L and scales 77 ohms.
5. Construct circle (3) through the origin and Z_L . It will intersect the vertical axis at -285 ohms (X_2).



13. Examples of 2-step impedance path from 75 ohms to 50 ohms in an L network.

6. Construct circle (4) through the origin and P2. It will intersect the vertical axis at -110 ohms (X_3).
7. When neither of the terminal points is on the horizontal axis, as in this case with Z_L and P2, it is necessary to compute the value of reactance involved in moving from Z2 to P2.

$$X_1 = \frac{X_2 \cdot X_3}{X_2 - X_3}$$

X_1 = added reactance

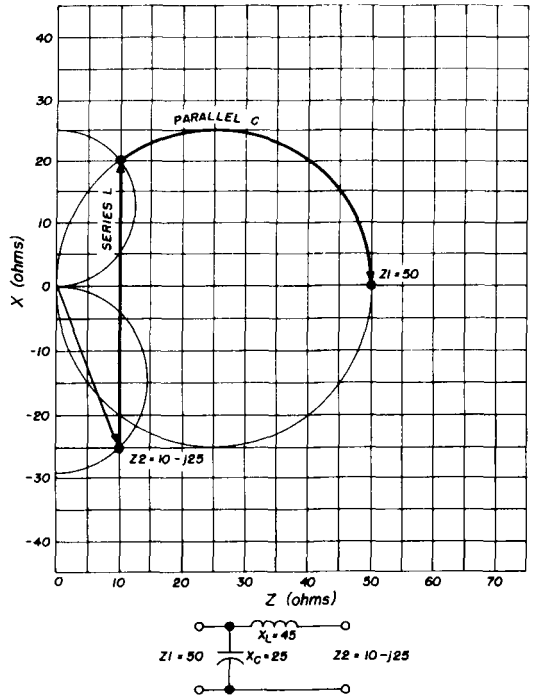
X_2 = initial reactance

X_3 = final reactance

$$X_1 = \frac{(-285) (-110)}{(-285) - (-110)} = -179 \text{ ohm capacitive}$$

8. Solution: $L_1 = j77$ ohms, and $C_1 = j170$ ohms.

In fig. 15 are examples of three different



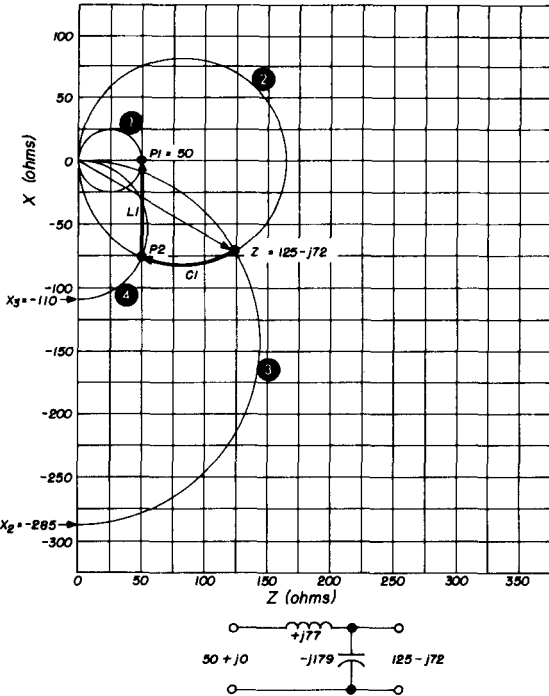
15A. Impedance path through matching network consisting of series L and parallel C.

choices of impedance paths in going from Z2 to Z1 using three network combinations to match a resistive 50-ohm load to a complex load of $10-j25$ ohms. Again, the "forbidden" path is not to be used because it passes through the origin.

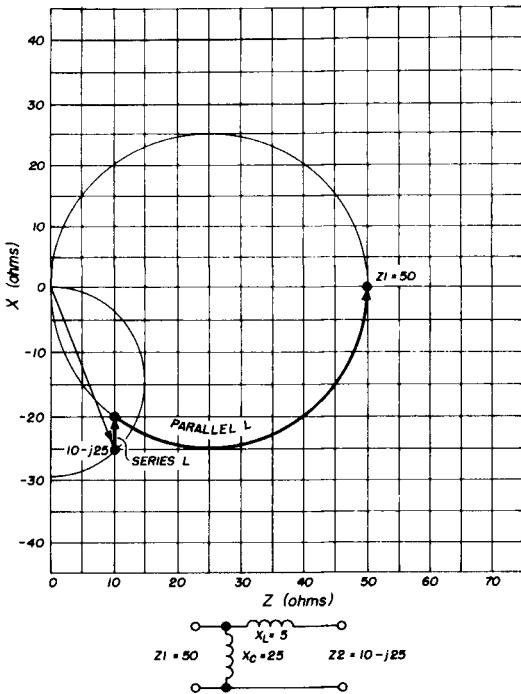
summary

We have shown examples of solving the most common impedance-matching problems using simple geometric methods. The following notes are offered in adopting these methods for solving a wide variety of problems.

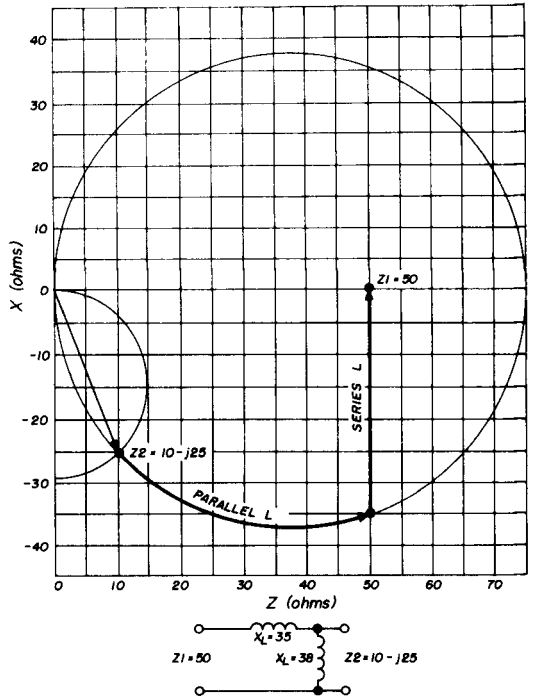
1. The L-network is one of the most useful circuits known for matching nearly all direct-coupled tank systems. The examples show how to match a high-resistance to a low-impedance reactive load. If the converse is desired, it is only necessary to convert the reactive load to its equivalent parallel components.
2. T networks are useful as harmonic attenuators in low-impedance transmission



14. Matching a 50-ohm resistive load to a complex load. The impedance path is from Z_L to P2 to P1.



15B. Impedance path through matching network consisting of series and parallel L, respectively.



15C. Impedance path through parallel and series L, respectively.

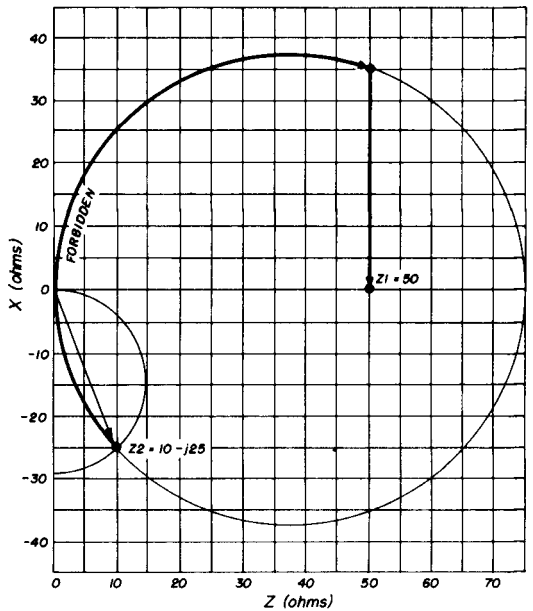
lines. These can be readily solved by treating them as two cascaded L sections and combining the capacitances.

3. The pi network is used to match a wide range of load impedances with reasonable tank-circuit Q. Contrary to some popular notions, the pi network will not match a tube to any length of wire. The circuit is load-limited by the ratio of tube load and circuit Q if it is to perform as an efficient transformer.⁵

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ham radio



15. Another example of impedance paths in network design. Three different 2-step paths are shown from Z2 to Z1 as well as the "forbidden" path through the origin.



**new life
for the
Collins 51J
receiver vfo**

The local oscillator
in this excellent receiver
can be restored
to like-new operation
with these
modifications

William I. Orr, W6SAJ, Eimac Division of Varian, San Carlos, California 94070

The Collins 51J series receiver (military type R-388/URR) is a valuable adjunct to any amateur station. Several articles have described modifications to make this superb receiver better suited to single side-band reception.^{1,2,3}

Available through surplus sales or MARS issue, the 51J receiver offers low-drift frequency readout capability from 500 kHz to 30.5 MHz. Indeed, a mint condition 51J with its 100 kHz crystal calibrator makes a good frequency meter for the home laboratory or amateur station in addition to providing excellent high-frequency and broadcast-band reception.

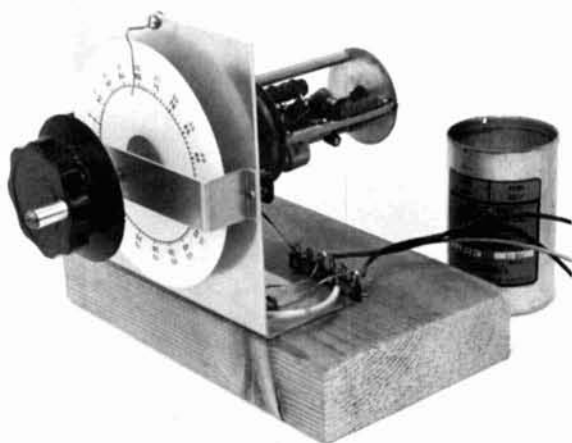
I've noticed that secondhand 51J receivers seem to be valued in proportion to the accuracy of tuning-dial calibration which, in turn, is a direct function of tuning linearity of the variable frequency oscillator (vfo)—the heart of the receiver. The better the vfo tracking characteristics, the greater the worth of the receiver. The difference in cost between a receiver having a good and a poor tracking characteristic is several hundred dollars.

vfo calibration shift

My 51J receiver was purchased secondhand in 1956. At that time, I made an accurate frequency check of the vfo and filed

the results. Over the years, I noticed a gradual, slow shift in calibration linearity. Finally, in early 1968, I found that correction was beyond the capability of the dial zero adjust (or fiduciary setting, as it's sometimes called).

A check with other owners of older 51J's indicated that their receivers had the same slow drift to a certain extent. Interestingly enough, in all cases, the calibration shift was in the same direction and of the same magnitude. That is, the vfo tuning range



Jig for Collins vfo adjustment. Oscillator cover is removed to expose adjustment coil, L-002. Shield must be replaced for calibration, as it shifts resonant-circuit frequency.

gradually contracted. Instead of tuning 1000 kHz with ten revolutions of the tuning dial, the tuning range was reduced to about 990 kHz with ten revolutions. This made each end of the dial in error by 5 kHz when calibration was established at the center of the tuning range. For example, when calibration was "on the nose" at 15 MHz, at 14.5 MHz the dial would read 14.505 MHz; and at 15.5 MHz, it would read 15.495 MHz.

The 51J instruction manual is full of exhortations about not tampering with the sealed vfo, otherwise frequency calibration will be degraded. True, there's an auxiliary

adjustment on the front of the vfo that can be used to restore tracking. However, in most older 51J's, the adjustment will have been "used up," and no further adjustment is possible.

modifications

This being the case, I felt my receiver's calibration was so far off that no further damage could be done to the sealed vfo unit if it was carefully opened and examined. Accordingly, the vfo was removed from the 51J (not without some trepidation), opened, modified, resealed, and replaced in the receiver. Results were so gratifying that I prepared this article to describe the modification, with the hope that it will benefit other owners of this fine receiver.

It should be noted that Collins approval of this radical surgery has not been obtained, and I doubt if such a modification, as described here, would meet with other than raised eyebrows. However, many 51J receivers have outlived their warranty. So if yours is one of these and suffers from the ailment described, the modification will restore receiver dial calibration to that comparable with a new set.

While modifying the vfo, several capacitors that have a notoriously short life can be replaced, thus enhancing the receiver's long-term reliability.

the variable frequency oscillator

This modification involves the Collins 70E-15 oscillator used in the 51J receivers. The unit tunes 2 to 3 MHz, with a generous overlap at each end of the range. Shaft rotation requires ten turns to cover the 1000-kHz range. Output voltage into an open load varies between 3.5 and 6 volts, at an operating potential of 150. Oscillator tube V-001 (see **fig. 1**) receives in-phase feedback voltage from amplifier tube V-002's screen circuit through capacitor C-008. The oscillator tank consists of trimmer inductor L-002, permeability-tuned inductor L-001, and tank capacitor C-001 in parallel with temperature compensating capacitors. The oscillator is tuned by moving the powdered iron core within inductor L-001. The core, or slug, traverses a lead

screw rotated by the receiver tuning dial. Tuning ranges and other data for the Collins vfo's are listed in **table 1**.

The over-all oscillator tuning range is established by adjustment of trimmer inductor L-002, which may be manipulated through an adjustment hole in the front

points have shrunk, and neither trimmer coil L-002 nor the zero adjust compensation device on the tuning dial will bring the end points within the correct range. When new, the vfo may be adjusted over a range of about 40 kHz, centered about the 1000-kHz tuning range (**fig. 2**). As the unit ages, the

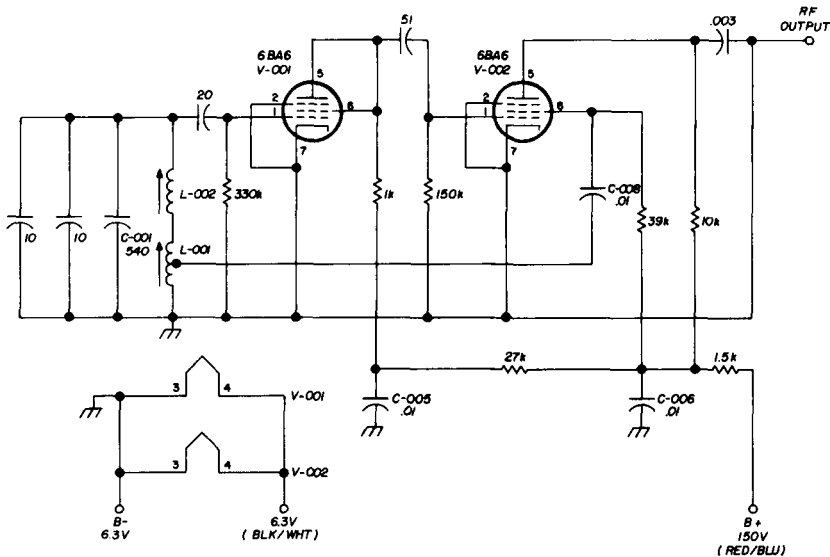


fig. 1. Collins 70E-15 vfo schematic. As tuning slug in L-001 ages, oscillator tuning range decreases until trimmer L-002 provides no more correction; L-002 is reworked to restore correct tuning range.

plate of the oscillator. With the aid of a special adjustment tool, L-002 may be tuned without removing the oscillator from the receiver. Vfo alignment by adjustment of coil L-002 is covered in the Collins instruction and maintenance manual (section 5.3.15).

When the receiver is new, this adjustment permits expansion and contraction of the vfo tuning range from a minimum of about 980 kHz to a maximum of about 1020 kHz. Proper adjustment of L-002's slug permits the tuning range end points to be moved sufficiently to ensure good calibration at the ends and center.

Alas, as the 51J receiver ages, it seems that the powdered-iron core of the main tuning slug ages also. At some future time, it will be found that the tuning range end

total range of L-002 remains about the same, but the entire range shifts in frequency as shown, until it doesn't include the desired correction range.

Luckily the slow shift of the vfo tuning range seems to decrease with time. Eventually stability is achieved, but at just about the time the user finds he has run out of vfo compensation because of the combined aging of the main tuning slug and the relatively restricted adjustment range of coil L-002.

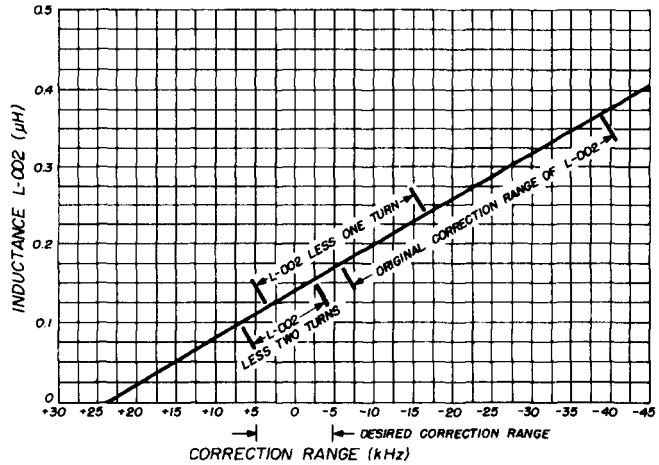
An astute student of Murphy's Law could have predicted this impasse; thus the question is raised: what can be done to re-establish the correct tuning range of trimmer coil L-002 so that an older 51J may be brought into calibration and allowance provided for future corrections, if needed?

vfo removal

In order to work on the vfo, it's necessary to remove it from the receiver and mount it in a temporary calibration jig, as shown in the photograph. To begin this task, remove the vfo tubes and the following panel dials: selectivity, phasing, main tuning, band change, antenna trim and bfo

As you remove the vfo, take care to catch and carefully retain the central portion of the flexible shaft coupler, which usually falls out at this point. Note that the upper-right screw holding the vfo, as viewed from the front, is accessible from the front of the receiver through a hole in the tuning gear by turning the "kilocycle" shaft to align the

fig. 2. Plot of trimmer coil L-002 inductance versus correction range. Removing one or two turns reduces over-all correction range, but moves it in proper direction to allow correction as shown.



pitch. Next, remove the front panel by removing 11 securing screws, and unhook the two dial lamps over the dial drum. Tilt the panel forward. Now, remove the plastic "kilocycles" dial from the vfo shaft, after first setting the vfo shaft at about the center of the tuning range.

Remove the three screws and lock washers holding the vfo to the chassis panel. Unsolder the two power leads (black/white is filament; red/blue is B-plus to pin 5 of the voltage-regulator tube). Unsolder the coaxial output cable from pin 1 of the 6BE6 mixer tube. The vfo is now free of the receiver.

The easiest way to remove the vfo is to lift it upwards through the top of the receiver, as the under-chassis area is blocked by other components. To do this, remove the bottom tapped panel spacer from the front of the vfo, the spacer otherwise will hit the shaft coupler and prevent the vfo from being tipped forward for removal.

hole over the screw.

Once the vfo is out of the receiver, mount it in the jig. Attach a flexible coupler to the vfo tuning shaft. When you remove the original coupling from the vfo shaft, note its location on the shaft **before** you remove it. This will allow it to be returned to the same position after completion of work. Normally, the coupling plate is flush, or nearly so, with the end of the shaft.

The plastic "kilocycles" dial and an extension shaft permit the vfo to be tuned during tests, and a makeshift pointer is mounted to the aluminum plate so dial calibration may be noted. Place the receiver aside, and cover the main drum dial with a cloth to protect its printed surface.

vfo adjustment

Apply filament and plate voltage to the vfo. It should draw about 12 to 15 mA plate current. Make a frequency calibration

chart of the tuning range by checking the 100-kHz points against a well-calibrated receiver tuned to the 2- to 3-MHz range.

Next, remove the vfo shield. The shield will shift the vfo frequency by many kHz when removed. It must be replaced when frequency measurements are made. While the shield is off, however, observe the movement of L-002's slug as you vary it. This will give you a feel as to the amount of expansion or contraction that this adjustment provides. In most cases, you'll find this control won't provide enough expansion for the correction range. A maximum tuning range of about 990 kHz per ten turns of the dial may be found; thus the dial must make about 10-1/8 revolutions for the 1000-kHz range.

Note also that the maximum tuning range is about 12 1/2 turns of the shaft, with the center point about 5 1/2 turns from the 2-MHz end. The most nearly correct tuning range will occur with L-002's slug withdrawn from the coil (minimum inductance).

replacing capacitors

Before you recalibrate the vfo, it's wise to replace certain capacitors. While they don't affect vfo calibration, they're bound to give trouble sooner or later. These are the two 0.01 μ F bypass capacitors, C-005, and C-006, located beneath the tube sockets, and the 0.01 μ F feedback capacitor, C-008. (The latter is inside the vfo can at the base of the main tuning coil, L-001.) All are "match stick" capacitors, rated at 200 Vdc. They short out frequently, especially when they age. Since the vfo must be removed to make the coil modifications, it's a good idea to replace these capacitors.

Capacitors C-005 and C-006 may be reached by removing the small U-shaped shield beneath the vfo tube sockets. The shield is soldered in place and can be easily removed. Replace C-005 and C-006 with 0.01 μ F, 600-volt disc ceramics. Resolder the U-shaped shield, making sure the new capacitors' leads don't short to the metal case or cover.

Feedback capacitor C-008 is located in the vfo at the base of the main oscillator

coil, L-001. Replace C-008 with a 0.001 μ F, 300-volt silver mica capacitor. Secure the new capacitor to the adjacent support terminal with a drop of epoxy cement. The vfo is now ready for final calibration.

calibrating the vfo

It's necessary to reduce the over-all inductance of the tuned circuit to achieve the proper tuning range. This is most easily done by altering the inductance of trimmer coil L-002. When new, L-002 has an inductance range of about 0.18 - 0.4 μ H (fig. 2). In order to bring the adjustment range within practical limits, one turn should be carefully removed from L-002's outer end.

Carefully unsolder L-002's terminal connection, and unwind the wire. Scrape the insulation one turn back from the end. Resolder the wire to the terminal at this point. Replace the vfo's cover, and make several frequency checks at different settings of L-002's slug. If the inductance setting of L-002 is correct, the vfo will tune the 1000-kHz range with ten turns of the shaft and with L-002's slug advanced about six turns into the coil. You should be able to expand and compress the over-all tuning range from 995 to 1005 kHz or more by adjusting L-002. If the vfo was very far out of adjustment initially, it may be necessary to remove an additional one-half turn from L-002 (see fig. 2).

The chart of fig. 2 shows that when L-002's inductance is decreased, its adjustment range is accordingly reduced. With one turn removed, the adjustment range is about 18 kHz; with two turns removed, it shrinks to about 8 kHz. Clearly, no more wire than is absolutely necessary should be removed from L-002, as the point of no return approaches rapidly.

Once L-002 has been adjusted to provide the proper tuning range, the vfo is ready to be returned to the receiver. Firmly bolt the vfo's cover into place. Set the vfo to approximately the center of its tuning range (about 2.5 MHz). Set the "megacycle" dial to an integral megahertz (15 MHz, for example).

table 1. Tuning ranges, operating voltages, and number of tuning dial revolutions to cover tuning ranges of the Collins receiver vfo's.

Type	Use	Tuning Range (MHz)	Filament Voltage	B+	Turns*
70E-1	ARC-2	1.0-1.5	12.6	250	10
70E-2	ARR-15	2.0-3.0	12.6	250	10
70E-3	ARR-15	0.450-0.550	12.6	250	5
70E-7A	75A-1	2.0-3.0	6.3	250	10
70E-8	310B 32V	1.6-2.0	6.3	180- 250	16
70E-10	708-A	0.600-0.800	6.3	250	10
70E-11	708-A	1.0-1.5	6.3	250	10
70E-12	75A-2 75A-3	1.955-2.955	6.3	150	10
70E-14	KW-1	1.6-2.5	6.3	210	16
70E-15	51-J	2.0-3.0	6.3	150	10
70E-23	KWS-1	2.75-3.75	6.3	210	10
70E-24	75A-4	1.955-2.955	6.3	150	10
70H-1	R-389	0.469-0.980	6.3	180	51
70H-2	R-390	2.455-3.455	6.3	180	10
70H-12	R-390A	2.455-3.455	6.3	180	10
70K-1	KWM-1	3.455-3.545	6.3	200	1
70K-2	KWM-2	2.5-2.7	6.3	130	2
70K-2	32S-1	2.5-2.7	6.3	130	2
70K-2	75S-1	2.5-2.7	6.3	130	2

*Number of shaft turns to cover vfo tuning range.

The first step is to replace the center portion of the vfo's shaft coupler on the mating coupler section of the receiver. It may be held in place by friction, plus a little heavy grease. Lower the vfo into position with a twisting motion, and when in place with coupling mated, temporarily lock it into position with two retaining screws through the front panel. Replace the bottom spacer (previously removed), and secure the third panel bolt. Rotate the vfo shaft to make sure the coupling doesn't bind. Then return it to an even "megacycle" position on the main dial.

The final job is to align the vfo shaft and the "megacycle" and "kilocycle" dials for correct readout. Tune in a signal of known frequency from a generator or WWV. Various shaft couplings should be slipped until calibration is correct, using the receiver bfo for zero-beat. The process is markedly speeded if the dial setting and

various shaft settings are not touched once the original positions are logged before removing the vfo. However, even if the shaft positions are inadvertently lost, no great harm is done. They may be re-established as long as an accurately known frequency is used for final calibration.

A number of Collins receivers, modified as described here, have dial calibrations accurate to within one kHz at any point on the dial. The zero-set adjustment need not be used unless a very accurate frequency readout is desired.

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2. W. M. Scherer, "More On Updated Improvements for the 51-J Receiver," CQ, December, 1968, p. 64.
3. P. H. Lee, "A Single Tube Product Detector," CQ, April, 1961, p. 50.

ham radio

frequency synthesis

A discussion
of some digital
frequency synthesis
techniques for
amateur radio
operators

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As the amateur bands become more and more crowded and the need for precise frequency control becomes greater and greater, advanced amateurs should abandon the familiar vfo and consider the more sophisticated, more accurate frequency synthesis. The techniques of frequency synthesis have been available for years, but it wasn't until the advent of integrated circuits and computer counting techniques that a practical method evolved.

Forty years ago, a vfo was accurate enough for most communication systems. Then the airwaves became crowded, channels were assigned, and soon (for all except the amateur) the vfo was not accurate enough. Enter the crystal oscillator with its excellent long-term frequency stability. Enter also a cost problem because each desired frequency required at least a separate crystal. This problem was overcome by combining a vfo with a crystal oscillator. When the frequency of a vfo is controlled by a crystal oscillator, the drift of the vfo is constantly corrected so that the long-term drift of the output signal is equal to that of the crystal oscillator itself.

One of the basic elements of frequency synthesis is the phase-lock loop. **Fig. 1** illustrates the basic phase-lock loop in which the output of a voltage-controlled oscillator (vco) constantly is compared with the frequency supplied by the reference source. The reference source usually is a crystal oscillator; the vco may be thought of as a vfo whose output frequency is determined not by a manual dial but by an electrical input.

Because of its long-term instability, the vco tends to drift off frequency. Any change in the output frequency is detected by the phase comparator when compared with the reference signal. When a phase difference exists, the phase detector generates a control voltage which returns the vco to the proper frequency. The long-term stability of the phase-lock loop output is that of the reference source.

voltage-controlled oscillator

The simplified schematic diagram of a typical voltage-controlled oscillator (vco) is shown in **fig. 2**. The components form a common-base Hartley oscillator circuit with L1, C1, C2 and D1 in the tank circuit. R2 and R3 form a voltage divider to establish base bias for Q1; C3 places the base of Q1 at rf ground. The output of Q1 is developed across R1 and L1. Any ac developed across R1 is fed back to the emitter of Q1 through C4 and the tap on L1; this positive feedback causes oscillation. Since the oscillation frequency is determined by the tank circuit, the resonant frequency of the tank circuit can be changed by changing the value of C1 or D1.

D1 is a variable capacitance diode (varactor) which, as long as it is reverse-biased, acts as a capacitance whose value varies in proportion to the dc voltage across the diode. By controlling the dc voltage across the diode, the resonant frequency also can be changed manually by changing the setting of variable capacitor C1.

Capacitor C2 isolates the dc control voltage from the transistor, and the rf choke in series with the dc control voltage, along with capacitor C5, forms a low-pass filter that prevents rf present in the tank circuit from being applied to the dc control lines.

pulse shaping networks

Since this article deals with pulse handling circuitry, this section will review some basic pulse shaping networks shown in **fig. 3**. Consider the clipper first. The diode shunted across the output clips the negative excursions of the input pulse (when the diode is forward-biased) but does not affect the positive excursion (when the diode

is reverse-biased). Reversing the polarity of the diode would leave the negative-going pulses in the output while removing the positive-going portion of the input waveform.

The clamper shifts the input waveform so that the largest negative excursion (10 for the input) occurs at 0 volts in the output. Thus, the dc component of the output is +10 Vdc, the largest negative excursion is 0 Vdc, and the largest positive excursion is +20 Vdc. Reversing the polarity of the diode would place the dc component of the output at -10 Vdc, the largest negative excursion at -20 Vdc, and the largest positive excursion at 0 Vdc. Note that the waveform is not distorted.

The differentiating network (or differentiator) is an RC circuit whose time constant is extremely short in comparison with the pulse width (pw) or pulse repetition time (prt) of the input signal. The fast, positive-going leading edge of the input pulse is immediately passed by the capacitor, and all of the output appears across the resistor. As the capacitor charges, more and more voltage appears across the capacitor and less and less across the resistor. When the negative-going trailing edge of the pulse appears at the input, it is immediately transferred to the output by the capacitor, and all of the voltage appears across the resistor.

As the capacitor charges, more and more voltage appears across the capacitor and less and less across the resistor. Thus the input squarewave pulse has been shaped into symmetrical positive and negative spikes coinciding with the leading and trailing edges (respectively) of the input pulse. Either the positive or negative portion of the output waveform could be eliminated with a clipper, leaving one spike for each input pulse.

The ramp-forming integrating net would be a simple low-pass filter if it were not for the diode across the resistor. When the positive-going leading edge of the input pulse occurs, the diode is reverse-biased, and all of the current flows through the resistor. As long as the load on the output is negligible, the current through the resistor is that necessary to charge the

capacitor. Initially, the current is relatively high, and most of the input voltage appears across the resistor. As the capacitor charges, more and more voltage appears across the capacitor, and because less current is required, less and less voltage appears across the resistor.

If the RC time constant is made relatively long in comparison with the period of the input waveform, the sloping portion of the output waveform will be a relatively straight ramp. When the negative-going trailing edge of the input pulse appears, the forward-biased diode provides an easy discharge path for the capacitor. It also couples the input directly to the output. Since the input is zero and the capacitor is quickly discharged, the output is zero.

phase detector

In the phase-lock loop illustrated in fig. 1, the variable output frequency was compared with the signal from the reference source. This is accomplished in the phase detector or phase comparator stage that is illustrated in fig. 4. In this circuit Q1 and Q2 are connected as a flip-flop. When power is first applied, one transistor conducts more heavily than the other because of natural circuit intolerances. Assume that Q2 conducts more heavily than Q1. The voltage at the collector of Q2 goes less positive, and is coupled through resistor R2 and commutating (speed-up) capacitor C2 to the base of Q1.

The negative-going voltage at the base of Q1 tends to cut off Q1, which results in a positive-going voltage at the collector of Q1. R1 and C1 apply this positive-going voltage to the base of Q2, increasing the forward bias on the base of Q2. Regenerative action occurs, and a stable state is reached with Q2 saturated and Q1 cut off.

The output (at the base of Q3) is effectively zero.

If a negative pulse (or the trailing edge of a positive pulse) is applied to capacitor C4 while Q2 is on, diode D2 is forward biased (by the positive voltage on the base of Q2), and the negative-going signal will be coupled to the base of Q2. This pulse momentarily cuts off Q2. The collector of Q2 becomes positive, and this positive-going voltage is coupled by R2 and C2 to the base of Q1, turning on Q1. The result-

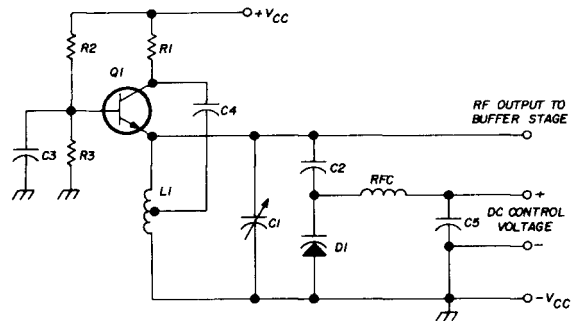


fig. 2. Simplified schematic diagram of a typical voltage-controlled oscillator.

ing low voltage at the collector of Q1 is coupled by R1 and C1 to the base of Q2, holding Q2 off. The output (at the base of Q3) is now positive. Thus, a second stable state has been reached, with Q1 on and Q2 off. Note that Q1 and Q2 cannot both be on or off at the same time.

At this point, diode D1 is forward-biased and diode D2 is reverse-biased by the voltages on the bases of Q1 and Q2 respectively. If a negative-going pulse is applied to capacitor C3, Q1 will be momentarily cut off. The collector of Q1 becomes positive, the base of Q2 goes positive, and Q2 turns on. The collector of Q2 goes less positive, the base of Q1 goes less positive, and Q1 is turned off. This returns the flip-flop to its original state: Q2 on, Q1 off. The output (at the base of Q3) is again low.

The timing diagram in fig. 5 illustrates

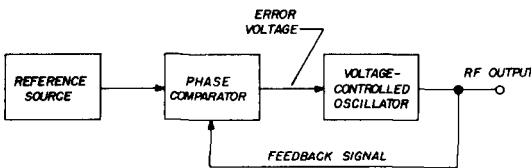


fig. 1. Block diagram of the basic phase-locked loop.

the waveforms present during the application of the flip-flop phase comparator. The reference signal from the reference source is converted into a squarewave by squaring amplifiers (not shown). This input is differentiated by capacitor C4 and the base-emitter resistance of Q2. The positive spike first formed by the differentiator at time T0 has no effect on Q2 since Q2 is already on. The negative spike formed on the trail-

from the reference input at time T6. Then, Q2 turns off, Q1 turns on, and the output is high. The output remains high until the next negative-going pulse from the variable input at T7. This turns Q1 off, Q2 on, and the output is low. The output of the stage is taken across load resistor R5 in the emitter circuit of buffer amplifier Q3. During the time period from T0 to T11, the reference signal leads the variable signal by 90°, and

TYPE	INPUT	CIRCUIT	OUTPUT
CLIPPER			
CLAMPER			
DIFFERENTIATING NETWORK			
RAMP-FORMING INTEGRATING NETWORK			

fig. 3. Pulse-shaping networks.

ing edge of the reference pulse at time T2 turns off Q2, and Q1 turns on (as explained earlier). Therefore, at T2 the collector of Q2 goes positive and the collector of Q1 goes to zero and the output is high.

The variable signal from the output of the vco is applied to squaring amplifiers, converted to a squarewave and applied to C3. The positive going spike at T1 has no effect on Q1 because diode D1 is reverse biased by the low voltage on the base of Q1. However, at T2 diode D1 becomes forward-biased by the positive collector voltage of Q2. When the negative spike appears at C3 at T3, it is coupled to the base of Q1, turning off Q1, and Q2 turns on. The collector of Q2 goes low, and the output is low.

The flip-flop is now in its original stable state of Q2 on, Q1 off, and it remains that way until the next negative-going pulse

the output pulse has a 25 percent duty cycle.

At T11 the phase of the variable signal shifts so that the variable lags the reference by 180 degrees. At T14, the negative-going reference signal turns off Q2 and Q1 turns on. The next negative-going variable signal occurs at T16, turning off Q1, and Q2 turns on. Thus, the output of the circuit is high from T14 and T16 and from T18 to T20, and the output pulse has a 50 percent duty cycle. The pulse width of the output signal is directly proportional to the phase difference between the two input signals and is greatest when the phase difference is 359 degrees. Note that the prt of the output is the same as the prt of the reference signal.

Applying the output from buffer amplifier Q3 to a low-pass filter will provide a dc voltage that is highest when the phase difference is greatest. If this voltage is ap-

plied correctly to the vco, it can keep the vco on the desired frequency.

frequency synthesizer

Most of the elements necessary to construct a digital frequency synthesizer have been covered. One possible configuration is shown in **fig. 6**.

The frequency standard is a crystal oscillator operating at 100 kHz. The 100-kHz output of the frequency standard (F_s) is applied to a fixed frequency divider. It divides input frequency F_s by a fixed divisor (M) to obtain reference frequency F_r . (It will become apparent later that the output frequency of the synthesizer may be shifted in discrete steps equal to the reference frequency. Thus reference frequency F_r must be low to make the steps practical. It is more practical to use a relatively high frequency crystal oscillator followed by a divider than it is to have a properly designed low frequency oscillator to provide F_r directly.)

By changing the divisor (M) it is possible to change the reference frequency, but this change is usually reserved to the design rather than the operational process. For example, if $F_s = 100$ kHz and $M = 10$, then $F_r = 10$ kHz. Or, if $F_s = 100$ kHz and $M = 100$, then $F_r = 1$ kHz. The latter is more practical for application in the amateur bands and is the frequency which will be used in the following discussion.

In a similar manner, the rf output of the synthesizer is divided, but by a variable divisor (N). Assume that the output fre-

quency is 3600 kHz. Then, if N is set (by means of switches on the control panel) to 3600, the output of the variable divider (F_d) is 1 kHz. This 1-kHz signal is compared with reference frequency F_r (also 1 kHz). Any phase difference is detected, and a pulse train is applied to the control voltage (low-pass) filter. The output of the filter is a dc voltage used to control the vco. When divided output frequency F_d equals reference F_r , the loop is "locked."

The beauty of the circuit is that the output frequency (F_o) can be changed merely by varying the divide ratio (N). Assume that N is changed from 3600 to 3590. The fre-

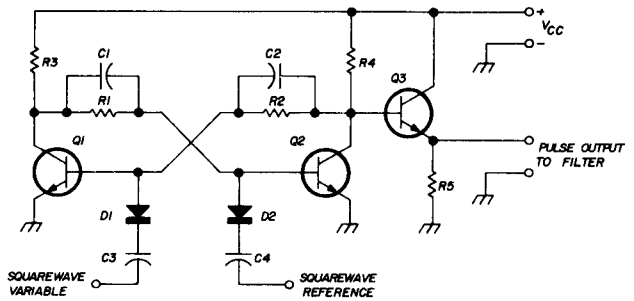
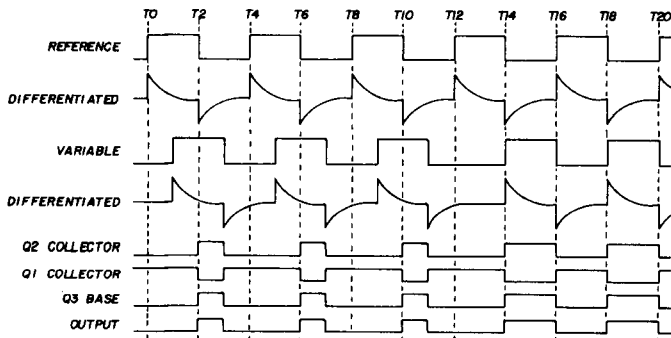


fig. 4. Phase comparator stage electronically compares a varying signal with a stable reference signal.

quency of the vco must now change to keep the reference frequency and F_d the same. At the instant of change, F_d equals 1.003 + kHz ($3600 \text{ kHz} \div 3590 = 1.003 + \text{kHz}$).

fig. 5. Timing diagram of the phase-comparator stage.



When this value of F_d is compared with F_r the control voltage changes to swing the frequency of the vco (F_o) lower. As the vco frequency approaches 3590 kHz, the control signal continues to change until finally the output frequency is 3590 kHz, F_s is 1 kHz, and the control signal is stabilized.

At this point (at the start of the sequence) the phase detector is not comparing phase but is detecting a frequency and phase difference. Without knowing more of the parameters of this system, it's not possible to say that an error of 10 kHz is within the capture range of the phase-lock loop. If the error is outside the capture range,

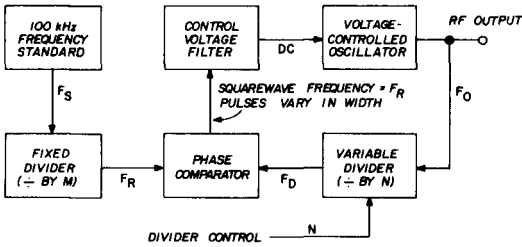


fig. 6. Block diagram of a digital frequency synthesizer.

the loop will be unable to correct the vco output to the new, desired frequency.

A large frequency error may be corrected in two ways:

1. The vco frequency could be changed manually until the output is within the capture range of the system.
2. Another control signal could be generated to rapidly sweep the vco through its entire range. As the vco frequency entered the capture range of the phase-lock loop, the loop would take over frequency control.

The first method is probably the least expensive, especially from an amateur's point of view. It would be a simple matter to monitor the dc control voltage; any control voltage fluctuations which persisted would indicate that the loop was "hunting" and

not locked. C1 in the vco could then be varied until the hunting ceased.

frequency comparator

If it's necessary that the synthesizer automatically set itself to a new frequency (as would be the case in a remote control situation), the circuit shown in fig. 7 could be used. The flip-flop is identical to that used in the phase comparator in fig. 4. It is shown here in its logic symbol form, which is easier to work with.

Briefly reviewing its operation, the reference squarewave is applied to the set (S) input, causing the Q output to go high until such time as the variable input signal (applied to the reset [R] input) causes the Q output to go low and the \bar{Q} (read NOT Q) output to go high. (To assist you, the following comparison is made to the flip-flop shown in fig. 4. The set input is C4, and the reset input is C3. The \bar{Q} output is the collector of Q2, and the Q output is the collector of Q1.) The frequency comparator in fig. 7 will provide the same phase difference signal as the phase comparator in fig. 4. In both cases the phase difference output is taken through a non-inverting buffer amplifier to minimize loading on the flip-flop.

The frequency comparison circuit makes use of the fact that if a frequency difference exists between the two input frequencies, the higher frequency signal will complete one cycle and at least start another before the lower frequency signal completes one cycle. Fig. 8 shows the waveforms present in the frequency and phase comparator shown in fig. 7.

Note that the frequency of the reference signal (S) is higher than the variable signal. In fact, between times T1 and T7 three cycles of the reference frequency occur while only two cycles of the variable frequency take place. Note also that the reference causes the Q output to be high and the variable causes the Q output to be low. (Remember that only the negative-going trailing edges of the pulses trigger the flip-flop.)

The following is an example of how a frequency difference is detected. The trailing

edge of the reference pulse at T4 causes the Q output to go high. The next trailing edge of the variable input does not occur until between T5 and T6. However, at T5 another reference pulse occurs. The leading edge of this pulse has no effect on the flip-flop (and would have no effect if it was a trailing edge, since the flip-flop is already set and the Q output already is high).

The Q output is connected to input E (AND gate A2). The other input (D) is reference signal S. At T5 both D and E are high because Q and S are both high. Therefore, output F (AND gate A2) is high causing

gate 3) indicates that a frequency difference exists, but the J pulse is rather short in duration. This pulse could be converted to a ramp-shaped pulse, but the rapid rise-time of the ramp would cause the vco frequency to change too fast to be detected by the phase and frequency comparator. One way to stretch the length of the pulse is to apply it to a one-shot as is done in fig. 7.

A schematic diagram of a one-shot is shown in fig. 9. Resistor R6 biases Q2 on. R2 and R3 apply a fixed positive voltage to the base of Q1. Since Q2 is on, it is drawing current through R1, and the voltage drop across R1 causes the emitter of Q1 to be

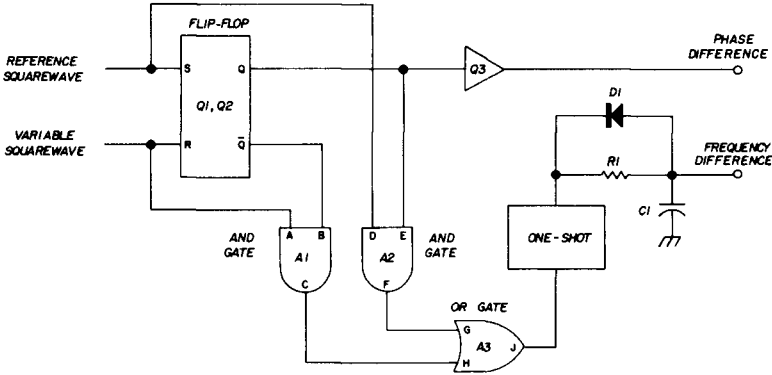


fig. 7. Logic diagram of a frequency and phase comparator.

input G (OR gate A3) to be high. Therefore, output J (OR gate A3) is also high. AND gate A1 is connected in a similar manner to detect simultaneous \bar{Q} and R pulses (which occur when the variable frequency is higher than the reference frequency). In either case, an output from OR gate A3 will occur, indicating that a phase difference of more than 360 degrees exists.

Now that a frequency difference has been detected, it must cause the frequency of the vco to change. One way to do this is to apply a ramp-shaped control voltage pulse to the varactor in the vco. This would sweep the vco through its entire frequency range.

Note in fig. 8 that the J output (OR

more positive than the fixed value of bias at the base of Q1. Thus, Q1 off and Q2 on is the stable state of the circuit.

In this state C2 charges through R4 and the forward-biased base-emitter junction of Q2. A positive trigger at C1 momentarily turns on Q1. The collector of Q1 goes less positive and this negative-going voltage is coupled instantly to the base of Q2 through C2, which turns off Q2. The collector of Q2, and therefore the output, goes high. As time passes C2 discharges through R6, but as long as the base of Q2 is more negative than the emitter, Q2 is reverse-biased and turned off. As long as Q2 is off, Q1 is held on because of the decreased current flow

through R1. When C2 has discharged sufficiently for Q2 to become forward-biased once again, Q2 turns on, and the drop across R1 again reverse biases Q1.

The values of R4, R5 and R1 are critical to the operation of the circuit because the current through Q1 has to be less than the current through Q2. This is so the emitter bias developed by R1 will not turn off Q1 when Q1 is supposed to be on, but will turn off Q1 when Q2 is turned on.

From the preceding circuit description it is apparent that the length of the output

phase comparator takes control of the vco frequency.

fixed divider

One of the elements necessary to the frequency synthesizer shown in **fig. 6** is a fixed divider that divides the frequency of the source (F_s) by 100. Dividing by 100 is accomplished by dividing by 10 and then dividing the result again by 10. Some manufacturers market a divide-by-10 scaler which produces one output pulse for each 10 input pulses. Another way of dividing by 10 is

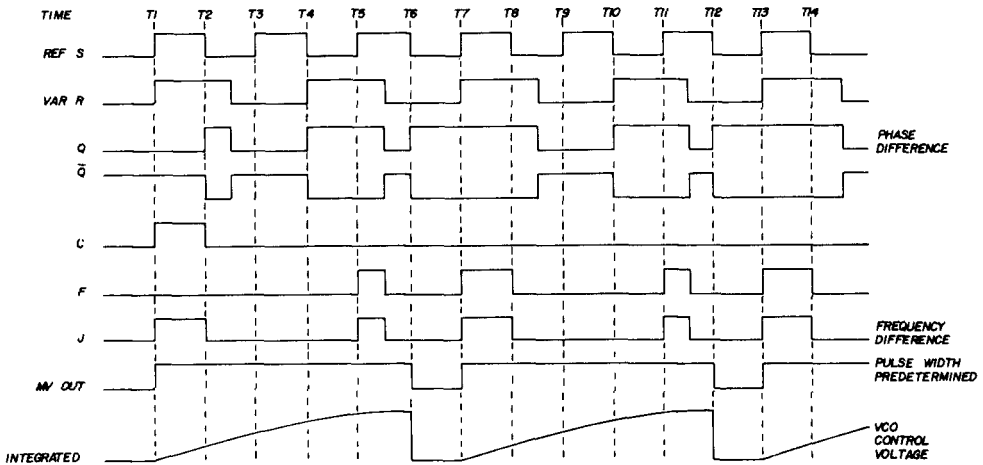


fig. 8. Timing diagram of the frequency and phase-comparator stage in **fig. 7**.

pulse is determined by the length of time it takes C2 to discharge through R6. By adjusting the RC time constant of C2-R6 it is possible to adjust the length of the output pulse. In **fig. 8**, the time constant is such that the output pulse is 5 times as long as the reference pulse. In practice it would be many times this length.

The one-shot output pulse in **fig. 7** is applied to the ramp-forming integrating net R1-C1-D1, resulting in the ramp-shaped pulse shown on the last line of **fig. 8**. This pulse is applied directly to a varactor in the vco to sweep its frequency. Once the frequency is within the capture range of the phase-lock loop, the ramp ceases, and the

the decade counter in **fig. 10**.

The flip-flops shown in **fig. 10** are similar to the flip-flops previously discussed (**fig. 4** and **7**) but have an additional input. The toggle (T) input provides symmetrical triggering in that a negative pulse causes the Q and \bar{Q} outputs to change state. If Q was high and \bar{Q} was low before the T pulse, then after the T pulse Q will be low and \bar{Q} will be high. The second T pulse again changes the state of the outputs so that Q will be high and \bar{Q} will be low. Applying a string of pulses to the toggle input will yield a pulse train from the Q output with a frequency that is one-half the frequency of the input. A similar out-

put may be taken from the \overline{Q} terminal, but it will be exactly 180° out of phase with the Q signal.

The flip-flops in **fig. 10** may be asymmetrically triggered as before by applying pulses to the set (S) or reset (R) inputs. A negative-going pulse at S will cause Q to be high, while a negative-going pulse at R will cause \overline{Q} to be high. When Q is high, \overline{Q} is low and vice versa. The output conditions cannot be predicted if both S and R are pulsed simultaneously.

In **fig. 10**, the Q output of A (Q_A) is connected to the T input of B (T_B); the Q output of B (Q_B) is connected to the T input of C (T_C). In A, the input pulse is divided by 2; in B, the output of A is divided by 2; and in C, the output of B is divided by 2. This means that the Q output of C (Q_C) is high after four input pulses and goes back to its original state after eight input pulses. Q_C is applied to the set (S) input of flip-flop D.

Note that Q_D is fed back to the R input of B and that Q_A is connected to the R input of D. During the following discussion keep in mind that the flip-flops are triggered only by the trailing edges of the pulses. At the beginning, it is common to assume that all Q outputs are low.

After the first input pulses, Q_A goes high. After pulse 2, Q_A goes low. This negative-going pulse is applied to T_B causing Q_B to go high. (The negative-going Q_A pulse also is applied to R_D , but has no effect because D is already reset). The third and fourth input pulses again cause Q_A to go first high, then low and the negative-going Q_A pulse that occurs causes Q_B to change state from high to low. The negative-going Q_B pulse causes Q_C to change from low to high. Pulses 5 and 6 again cause Q_A to go first high, then low and the negative-going Q_A pulse causes Q_B to change from low to high. This positive-going pulse has no effect on C, and Q_C remains high. Input pulse 7 causes Q_A to go high, but this has no effect on the remaining circuitry.

The action of the flip flops up to this point has been identical to that of a regular binary counter. From this point on the feedback paths play an active part in the opera-

tion of the counter. The trailing edge of pulse 8 causes Q_A to go from high to low. This negative-going pulse is applied to T_B and R_D . The negative-going pulse on T_B causes Q_B to go from high to low, and this negative-going pulse causes Q_C to go from high to low. The negative-going pulse from Q_C is applied to S_B . Therefore, there are now two pulses applied to D which seemingly contradict each other (S_D tries to make Q_D high and R_D tries to make Q_D low). Such is not the case, however. The propagation delay of the flip-flop chain removes the contradiction. The R_D pulse is coupled instantly from Q_A but the S_D pulse arrives only after B and C have changed state, so that by the time the S_D pulse arrives, the R_D pulse has lost its punch and the S_D

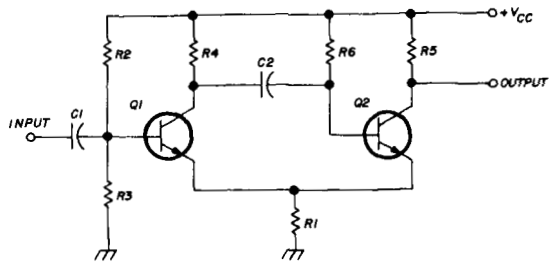


fig. 9. Emitter-coupled one-shot circuit.

pulse causes Q_D to go high.

Following pulse 9, Q_A changes from low to high, but this positive-going pulse has no effect on the remaining circuitry. After input pulse 10, Q_A goes low, and this negative-going pulse causes Q_D to go low also (because the Q_A pulse is applied to R_D). When Q_D changes from high to low, the negative-going pulse from Q_D is applied to R_B holding Q_B low so that the negative-going pulse at T_B (from Q_A) cannot cause Q_B to change state. Q_C is already low.

After ten input pulses, all flip-flop Q outputs are low, exactly the way they were when the counting started. The same sequence is repeated for the next and all following sets of ten pulses. The output from the decade counter is taken from Q_D . Note

that there is one pulse for every ten input pulses.

Fig. 10 also shows a simple connection to Q_A that provides a divide-by-2 output from the same counter. Note the waveform for Q_A . It contains one output pulse for every two input pulses. The same output

While I have not been able to delve into all of the design considerations, it is hoped that these notes have cleared away enough of the fog surrounding frequency synthesizers to stimulate some "research and development" activity among those amateur radio operators who have cried, "I've built

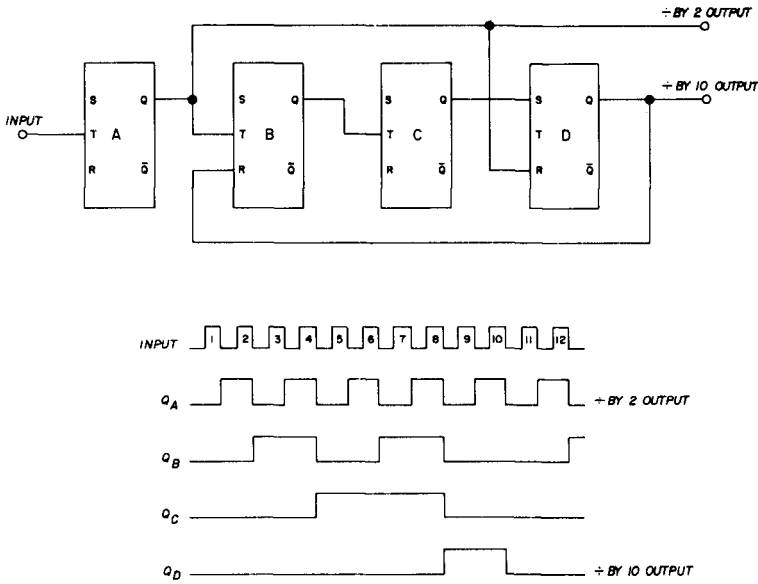


fig. 10. Logic and timing diagram of a decade counter with an auxiliary divide-by-two output.

could be taken from $\overline{Q_A}$, but it would be 180° out of phase.

variable divider

By selectively modifying the feedback paths, it is possible to build counters that will divide by numbers other than 2 and 10, but the design and operation of a variable divider is beyond the scope of this article. It should be noted that the variable divider shown in fig. 6 should divide F_0 by 3500 through 3999 if the output of the synthesizer is to be within the 80-meter amateur band.

summary

I hope that this article has removed some of the mystique about frequency synthesis.

everything there is to build from a spark-gap transmitter to an ssb transceiver." Here is something new to challenge you—I'd be interested to hear what develops.

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ham radio



K7YZZ in Bellevue, Washington is fully equipped for sstv operation.

slow-scan television

The principles
of this
narrow-band system
are discussed,
with some ideas
on how to get started

Ralph E. Taggart, WB8DQT, 1109K University Village, East Lansing, Michigan 48823

The term "slow-scan television" (sstv) is appearing more and more often in the amateur literature. However, from comments of fellows listening to the slow-scan net, it seems that few realize what it's all about or what can be accomplished with this mode. This article provides answers to some basic questions I've run into, both over the air, and at several meetings where I've exhibited my gear.

what it is

Slow-scan television is a narrow-band image transmission system. A 120-line picture is transmitted every eight seconds. The narrow-band part of the definition is important, because a slow-scan picture requires significantly less bandwidth than a standard phone signal. Sstv is now authorized in Advanced and Extra-Class phone segments of the 80—15 meter bands, the entire phone segments of 10 meters and our vhf and uhf assignments. Every weekend pictures are exchanged between suitably equipped stations throughout the U. S. Pictures have been transmitted between the United States and England, the United States and Antarctica, and between Canada and Sweden.

About the only limitation to the DX capabilities of sstv is the lack of suitably equipped foreign stations. Interest in sstv is rising rapidly in Europe, Africa and Australia, so it appears that a new era of international communications activity is just ahead.

equipment

Present regulations require single sideband for sstv on 80 through 10 meters, while any phone mode may be used in the appropriate parts of the vhf and uhf bands. Standard transmitters and receivers are used for slow-scan work. Collins S-line equipment is used at W8SH, the club station of the Michigan State University where contacts have been made with Canada, Sweden and several states, including Alaska. Other amateurs have been using transceivers with success. The only additional gear includes a picture monitor and camera, with their power supplies and control circuits. The picture monitor is connected to the station receiver audio output, and the camera is connected to the transmitter audio input.

sstv signal composition

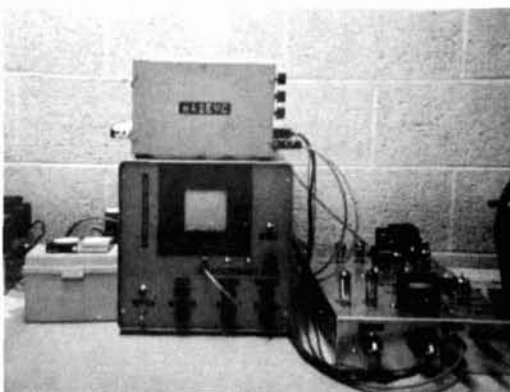
Any television system must transmit the following types of information:

1. Sync signals to ensure that the received picture is in step with the picture being transmitted. These are vertical pulses to start each picture or frame, and horizontal pulses to start each scanning line.
2. Video information, which produces black, white, and gray values during readout of each scanning line.

A single slow-scan frame transmitted on 14 MHz by W4CCG, Manassas, Virginia, and received by W8SH, East Lansing, Michigan. The resolving power of the 120-line system is obviously quite adequate.



The combination of sync and video information comprises the composite television signal. The original series of sstv articles by MacDonald described a system in which the composite signal consisted of an a-m tone or subcarrier.¹ Early experiments, both on the air and in the laboratory, indicated that the subcarrier a-m signal was subject to fading and interference.^{2,3} The system was then modified to have a composite signal consisting of an fm audio subcarrier.³ The equipment was adjusted so that the sub-carrier fre-



The author's equipment at W8SH.

quency was 1200 Hz during sync pulses, while the video changed linearly from 1500 Hz (black) to 2300 Hz (white). The vertical sync pulse width was 30 ms and was repeated once every eight seconds. The horizontal pulse width was 5 ms, with a repetition rate of 15 pps. This resulted in a 120-line raster with an aspect ratio of 1:1, which required eight seconds from start to finish (fig. 1).

The subcarrier for a single line scanning a gray scale is shown in fig. 2. At A we have the 5 ms pulse of 1200 Hz, which starts the scanning line. The video information ranges from white at B to mid-range gray at C, to black at D, and back to white at E. F represents the 1200-Hz pulse, which starts the next scanning line. Since the 1200-Hz sync pulses are in the infra-black range, the trace is blanked during the retrace interval. With more complex picture material, the sync

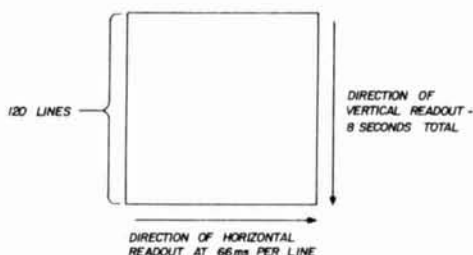
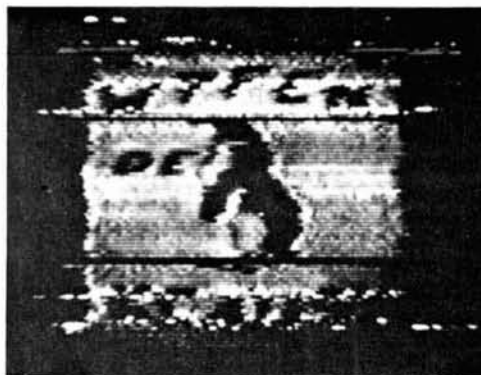


fig. 1. Slow-scan television raster. Aspect ratio is 1:1; readout time is 8 seconds.

pulses would remain the same, but the variations in video information would, of course, be far more complex. The composite slow-scan signal is thus an audio tone that varies in frequency between 1200 Hz and 2300 Hz, a total bandwidth of 1.1 kHz. The signal may be recorded on a standard audio tape recorder, since we are dealing with a mid-range audio tone and not the complex wide-band signal of standard television.

The photograph of a single slow-scan frame shows the resolution of the 120-line system. This signal was recorded off the air using a portable tape recorder with a tape speed of 3-3/4-inches per second. It was then played into the monitor for photography. A cathode-ray tube with a long persistence phosphor (P7) was used in the monitor so that the entire picture could be observed despite the extended readout time.



Single frame of a transmission from KC4USV, Antarctica, as received by W7FEN. The echo on the right side of the penguin is due to multipath propagation.

the monitor

The first step for slow-scan operation is to build a monitor for picture display. The most commonly used circuit was described by MacDonald.⁴ My monitor, shown in the photo, was built from this article. Cohen⁵ described an economical approach to the construction of this monitor using a surplus radar tracking set. This has been used successfully by many amateurs.

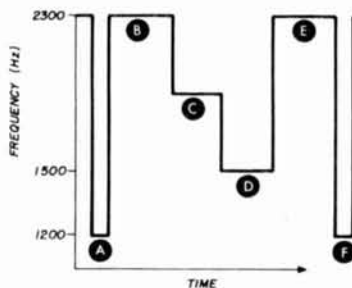


fig. 2. The fm subcarrier frequencies as functions of time. Extremes of tone values, white to black, occupy a bandwidth of only 1:1 kHz.

There's nothing particularly critical about monitor construction, since only audio frequency signals are processed in the unit. Well-filtered power supplies and shielded leads in input circuits will prevent hum pickup, which is probably the biggest single factor to be avoided. Most of the parts, including the cathode-ray tube, are available from surplus.



Single frame from a 20-meter transmission from W7FEN. W7FEN was using independent sideband at the time with the picture on the upper sideband and the voice on the lower.

Once a monitor has been completed, it is best aligned using a pre-recorded slow-scan tape. I'll be happy to provide such a tape to anyone actually constructing a monitor. Most operators will also make simultaneous recordings of incoming signals to provide a permanent record. It can be played back as often as you wish. The network of fig. 3 will allow visual and aural monitoring as well as recording.

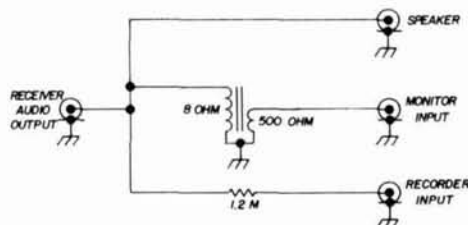


fig. 3. Circuit for visual and audio monitoring of sstv signals. Receiver i-f pass-band should be at least 2.5 kHz to avoid distortion caused by interference.

single sideband operation

When receiving pictures transmitted on single sideband, carrier insertion must be as precise as possible if the subcarrier frequencies are to be reproduced accurately. Small errors in carrier insertion will result in slight shifts in the gray scale, while large errors will usually mean no pictures at all due to the inability of the monitor to trigger properly on the sync pulses. Proper carrier insertion is easy if the monitor is in use, but may be a problem if you are recording "blind" for later playback. In this case, it is best to wait for a voice transmission from the station and tune for the most natural-sounding voice quality. Although this may sound like an indefinite procedure, it is surprisingly easy and will almost always be close enough for good picture rendition.

A signal of S4 or S5 on the hf bands will produce a readable picture if a reasonably clear channel is available. Signal levels higher than S9 will give "tape quality" pictures in the absence of strong interference. Since interference is the limiting factor in hf reception, the receiver should have a narrow i-f

response; not more than 3 kHz, and 2.5 or 2.1 kHz is even better. If the receiver i-f response is too broad, an external audio band-pass filter with cutoffs at 1 and 2.5 kHz would be a worthwhile addition.

vhf and uhf operation

Operation in the vhf and uhf bands is also feasible, but here the limiting factor is usually the signal-to-noise ratio rather than interference. The use of a-m or narrow-band fm on vhf eliminates the carrier insertion problems associated with ssb, but just as in normal phone operation, the use of ssb will result in a sizable increase in reliable range. I've been successful in transmitting sstv pictures about 100 miles on two meters using just 75 watts of a-m, so this type of operation should not be overlooked.



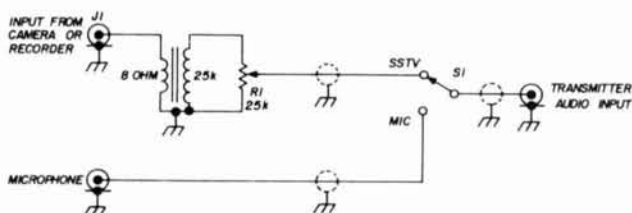
On-the-air shot of W9NTP. Here Don is adjusting the slow-scan monitor. The shuttered camera above the operating position is normally operated in real time.

Once the receiving gear is set up and working, the urge develops to send pictures. There are two general types of picture generators now in use—the flying-spot scanner (fss) and the vidicon camera. The fss is suitable for transmitting from photographs and other printed material. An excellent unit of this type has been described by Hutton.⁶ A number of operators are presently using units of this type. A more versatile approach is a live vidicon camera, described by MacDonald in a three-part article in *QST*.⁷ This is

uses the first of the two approaches, but both are highly satisfactory.

Although some live transmissions are made, most operators record their pictures for later playback over the air. This technique permits a maximum variety of material to be transmitted in as little on-the-air time as possible, since the tape may be edited as it is put together. Some provision must be made to feed the source (camera or recorder) into the transmitter audio input. The circuit of *fig. 4* is useful for this purpose.

fig. 4. Schematic for feeding video and audio signals to the transmitter. With recorder or camera level preset, video and audio input can be switched without changing transmitter audio gain control.



probably the most commonly constructed camera to date and gives very good results.

As originally described, the camera uses a special slow-scan vidicon, which is no longer available on the **gratis** basis described in the original articles. To get around this problem, many amateurs have experimented with standard vidicons. The procedure described by Taggart⁸ requires no modifications of the original circuit, while that of Hutton⁹ involves changes in the vidicon and video amplifier circuits. My camera (in the photo)

The transmitter audio gain control is set with the microphone at your normal speaking level. With the recorder or camera feeding J1 at some preset level, S1 is placed in the slow-scan position, and R1 is adjusted for the same level as when the microphone was used. If no changes are made in the recorder or camera level, you can then switch back and forth between voice and picture with no changes in the transmitter gain control. During the first few attempts at transmitting sstv, it is best to keep an eye on the final amplifier plate current. The constant amplitude of the fm subcarrier runs the final at a pretty stiff duty cycle, and a blower or slightly reduced power level may be required if the final tubes are gassy or the transmission line standing wave ratio is high.

sampling techniques*

Many amateurs engaged in sstv formerly experimented with wideband tv on the 432 MHz band, so they already had vidicon cam-



Slow-scan tv equipment used by W4UMF includes the hybrid monitor to the left and the transistorized vidicon camera in the center.

*This material on sampling techniques was originally presented to the FCC in a sstv progress report, "Slow-Scan Television Activity in the Alexandria, Virginia, Area," 27 September, 1968, by T. J. Cohen, W4UMF, D. Harmon, W4CCG, and D. Veazey, W4ABY.

eras which produced standard non-interlaced pictures suitable for conventional television receivers. If they could use these cameras in a slow-scan system it would provide an economical and versatile approach to sstv. Indeed, the following idea was quick to take form: if some way could be found to **sample** different portions of successive fast-scan pictures, the conventional video sources already available could be used as part of a slow-scan camera.

The first amateur slow-scan sampling sys-



Don Miller, W9NTP, is well equipped for sstv work. Equipment includes the sampling slow-scan camera to the left, the shuttered camera, upper right, and both slow- and fast-scan monitors.

tem was designed and built by Don Miller, W9NTP, in 1966-1967. This system, which used a vidicon camera as a video source, sampled 120 successive fast-scan pictures to produce one slow-scan frame. The sampled pictures, which were first aired on the Navy MARS sstv net in 1967, were judged to be as good as those produced by sstv cameras using special slow-scan vidicons⁷. Miller's circuit design was made available to the amateur community in late 1967; we built and operated a system based on this design in early 1968. Complete circuit details for Miller's sampling camera have been published by CQ^{9,10}

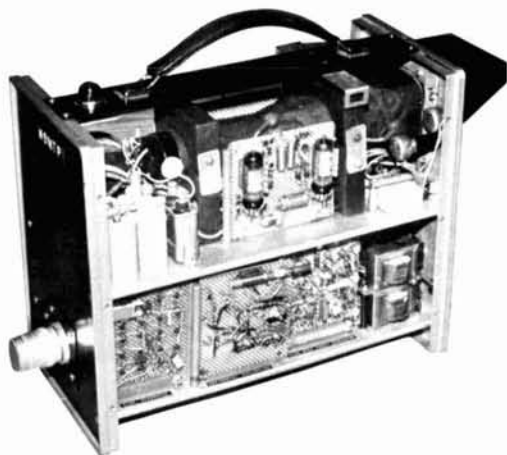
Recently, Watson and Horne¹¹ described a slow-scan sampling camera designed by the Research and Developments Labs, Northern Electric Co., Ltd. (Canada). Though little is known of this system, it works on

the same basic principle as Miller's camera: different portions of successive fast-scan pictures are sampled to produce a slow-scan frame.

Sampling-type sstv cameras are now used by at least three amateurs (WB6ZYE, W9NTP and VE3EGO), and construction is contemplated by more. With the growing interest in sampling systems, the need arises for a brief, but lucid, review of sampling techniques.

The block diagram for a sampling-type slow-scan camera is shown in **fig. 5**. A conventional fast-scan camera (with a fast-scan vidicon) is used as a video source. However, as seen in **fig. 5** a line-locked 15 Hz sawtooth waveform is generated in the system and imposed on the vertical deflection coils of the vidicon yoke (the 15 Hz oscillator also generates the slow-scan line sync and blanking pulses). The fast-scan video output now has a frame frequency of 15 Hz; the line frequency remains unchanged at 15,750 Hz.

The modified fast-scan video is fed to the sampler circuit which acts as an electronic gate, "opening" and consequently "sampling" the video at times dictated by the output of the Schmidt trigger sliding-pulse generator. This sliding-pulse genera-



Sampling camera built by W9NTP. The upper level houses a P7 monitor for both fast-scan and sampled slow-scan tv; the lower level is a fast-scan camera with a sampling circuit to provide slow-scan output.

tor is driven by an 8-second ramp waveform and the 15,750 Hz pulses from the fast-scan camera. The resultant output of the Schmidt trigger is a sliding pulse which moves with an 8-second period and has a 15,750 Hz rate.

Once sampled, the video appears as a series of spikes, with the amplitude of each spike equal to the amplitude of the fast-scan video signal at the instant the gate was opened. These pulses are very short in duration, however, and thus it is necessary

tures are shown diagrammatically in **fig. 6**. The sampling action starts in the upper left corner of the fast-scan picture. Every $1/15,750$ th of a second, roughly, a video sample is taken, the effect being to sweep the image downward and to the right (remember, the sampling pulse is sliding in time). Since the vertical frame rate is 15 Hz, 1050 samples are taken before the sampling pulse returns to the top of the picture. Each return is slightly to the right of the previous scan, and in this way, the

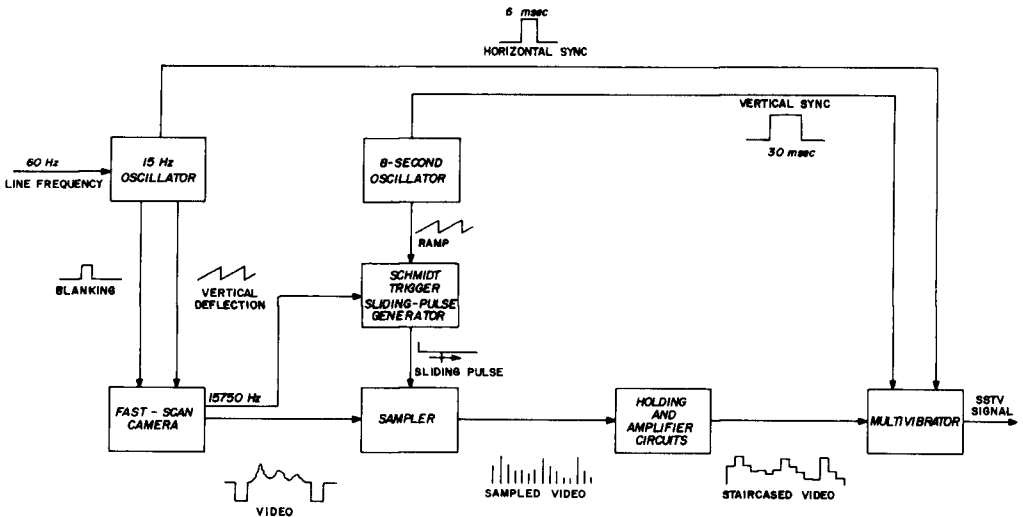


fig. 5. Block diagram of a sampling-type slow-scan television camera.

to "hold" a given sample at its peak amplitude until the next spike appears. The holding circuit performs this function, and its output, the "staircased" video, is amplified and fed to the multivibrator. Slow-scan horizontal and vertical sync pulses are also fed to the multivibrator, and together with the video input, a composite slow-scan signal is generated with the following characteristics:

1200 Hz	Sync
1500 Hz	Black
2300 Hz	White

Gray levels generate signals between 1500 and 2300 Hz.

Let's examine the sampling method in detail. Fast-scan and sampled slow-scan pic-

entire fast-scan picture is eventually sampled. With a vertical frame rate of 15 Hz and a sampling pulse which slides with a period of 8 seconds, the sampled slow-scan picture consists of 120 lines and is made up of successive portions of 120 fast-scan frames.

When the slow-scan picture is displayed, the 15 Hz frequency is now the line frequency and the vertical frame period is 8 seconds. This results in a sampled slow-scan picture which is both rotated and inverted. However, this presents no problem. For fast-scan cameras with identical vertical and horizontal yoke windings, it is only necessary to interchange (with a switch) the horizontal and vertical deflection leads, and

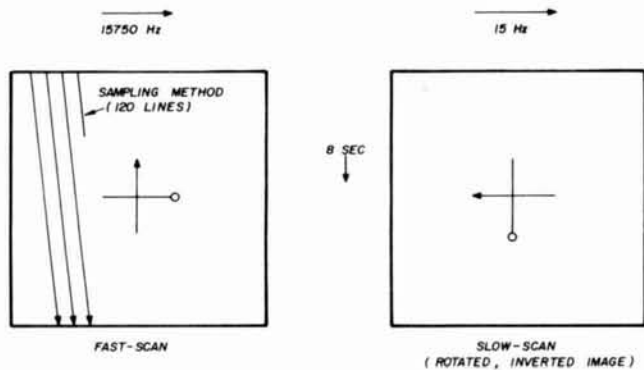
reverse the "new" set of vertical deflection leads.

With this sampling technique a conventional vidicon camera can be used to produce slow-scan television pictures. Though the subject to be televised must be held fixed for the entire 8-second sampling period the slow-scan pictures produced by a sampling system are of comparable quality to the excellent images produced by cameras using slow-scan vidicons (e.g. the WL-7290). The fact that the sampler camera uses a fast-scan vidicon and can be tuned

on the field-sequential system for transmitting color television pictures. This system, developed by Dr. Peter Goldmark of CBS Labs, and used for the first color tv broadcast in 1940, was rejected by the FCC for the United States standard. However, simplicity of the system (it requires only one-third the components required by a conventional color tv camera) results in reduced camera size and weight and makes it ideal for many medical, industrial and space applications.

In the field-sequential system of picture transmission, a color wheel containing red,

fig. 6. Fast- and slow-scan images.



up in "real time" are but two of the reasons why sampling systems are becoming so popular among sstv enthusiasts.

slow-scan color tv*

Recent color transmissions from the Apollo spacecraft have once again focused attention

green and blue filters is spun in front of a black-and-white television camera. The resultant black and white pictures, in sequence, contain the color information as seen through the filters. These black and white pictures are called the separation pictures. If the separation pictures are displayed on a crt and viewed through a camera-synced color wheel, the persistence of vision of the human eye will cause the original picture to be reproduced.

On February 7, 1969, Theodore Cohen and Wade Tarr succeeded in reproducing the first pseudo-field-sequential color picture transmitted by slow-scan television; color synthesis was achieved with subtractive¹ synthesis techniques. Working independently, WB8DQT reproduced the first additive-synthesis color sstv picture on February 13. Further experimentation by Cohen and Tarr led to a method of sstv color transmission which used quick-process-

*This section on slow-scan color tv was prepared by Ralph Taggart, WB8DQT, Theodore J. Cohen, W4UMF and Wade L. Tarr.



Solid-state slow-scan sampling camera built by Syd Horne, VE3EGO, and designed by Doug Watson.

ing Polaroid color film for both the color analysis* and color synthesis processes.

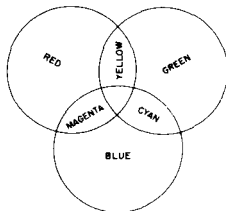
field-sequential color systems

The field-sequential method of color transmission is shown diagrammatically in **fig. 7**. The subject to be televised is a black card containing three circles—one red, one green, and one blue (the additive primary colors). These circles are viewed by a black-and-white television camera, the light first having passed through a spinning color wheel. The wheel contains wedges of red, green and blue filters. If the color wheel is synced to the black-and-white camera's frame rate such that successive frames are viewed through successive filters, the first frame in a three-frame set will contain that color information which passes, say, through the red filter. (Note that it is not necessary to synchronize the color wheel to the frame rate—it is done here only to simplify the explanation of the sequence of events. In usual practice the rotation of the color wheel is greater than the camera's frame rate.)

Since a filter passes light of its own color, only the light from the red circle will image on the camera's pick-up tube. This will be televised as a white circle while the other circles and the black background will be televised as black areas. Following in sequence will be a frame containing a white circle in

*In 1861 James Maxwell demonstrated the principles of three-color photography. He analyzed a landscape through red, green and blue filters, and made three black-and-white lantern slides. Then he projected the slides through red, green and blue filters and produced a color picture of the landscape by superimposing the three pictures. Producing a color image in this way is called **additive color synthesis**.

When white-light sources are projected through red, green and blue filters, and allowed to overlap as shown at the right, white is produced where all three colors are superimposed. There are also three other colors produced: cyan (white light minus red), magenta (white light minus green) and yellow (white light minus blue). This suggests that color synthesis may be performed by **subtractive** mixing using cyan, magenta and yellow. Subtractive color synthesis is the basis of our present color photography and color printing processes.



the green circle's position, and a frame containing a white circle in the blue circle's position. The three-frame sequence constitutes a **color analysis** of the color subject. Since color analysis information is transmitted in sequential frames, this system of color transmission is called the field-sequential system. (The present U.S. color-tv standard uses a dot-sequential system).

Upon receipt of the black-and-white color-separation pictures, the images are displayed on a conventional cathode-ray tube. However, the pictures must be viewed by the human observer through another spinning color wheel. If the viewing color wheel is synced

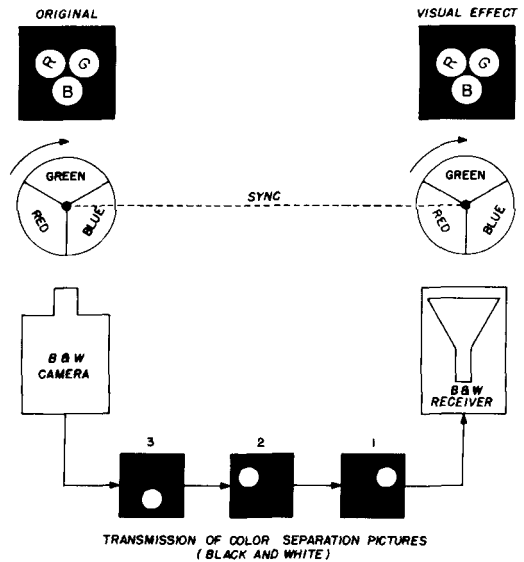


fig. 7. Field-sequential method of color transmission.

to the color wheel used in the color-analysis phase—and they must be synced to reproduce the color image—an observer's eye is presented with the following sequence of color pictures: frame 1, red circle on black background; frame 2, green circle on black background; frame 3, blue circle on black background; frame 4, same as frame 1, etc.

Because of the persistence of vision of the human eye, each frame is stored in the eye for a fraction of a second, and if the three-frame sequence is viewed in rapid succession,

the observer sees the original color picture. That is, the eye acts as a momentary storage device and integrates the three primary color images into a composite color picture.

At this point, you're probably wondering how a color picture is actually transmitted by slow-scan television. After all, slow-scan tv reads out one frame every 8 seconds, hardly short enough for the eye to integrate three frames into one color picture. The answer to this apparent paradox is that while three sstv separation frames are transmitted in sequence, **color film**—not the eye—is used to synthesize (integrate) the pictures.

Although the first slow-scan color picture

in a clearly defined sequential fashion. Finally, in the synthesis phase, the original scene is reproduced by sequentially viewing the set of separation pictures through primary-color filters.

sstv color analysis

The purpose of the color analysis phase is to yield a set of black-and-white separation pictures. If the television imaging system has a flat spectral response in the visible region, separation can be achieved directly by taking three successive television pictures of the color object through each of the primary-color filters. Although the imaging systems



These black-and-white color-separation prints show the red, green and blue (from left to right) components of the original scene.

was reproduced using subtractive synthesis, later experiments indicated that additive synthesis is more applicable to amateur work. Two basic additive synthesis methods have been investigated to date. One method requires a darkroom and is rather complex; the second method uses direct-write techniques, and can, with the use of high-speed color film, produce color pictures directly off the sstv monitor.

This method of transmitting and receiving color pictures can be broken down into three distinct phases: analysis, transmission and synthesis. In the analysis phase the original color picture is viewed sequentially through red, green and blue filters; the three black-and-white separation pictures obtained contain all of the information required to reproduce the original scene. In the transmission phase the separation pictures are transmitted

used by amateurs do not have absolutely flat response, flying-spot-scanners using 931A photomultiplier tubes and sstv cameras using conventional fast-scan vidicons exhibit satisfactory response characteristics.

For indirect color analysis a camera loaded with black-and-white panchromatic film is used. Both 35 mm and Polaroid cameras have been used for this purpose. Again, three separation pictures must be taken—one each through a red, a green and a blue filter. After the three black-and-white separation pictures have been printed, they may be televised using any sstv imaging system. The pictures are then recorded on magnetic tape for subsequent transmission.

sstv color transmission

The end result of the analysis phase is a recorded tape with ten or more frames each

of the red, green, and blue separation pictures (again, these are black and white pictures). Since the sstv sync and video information is all within the audio bandpass, the pictures may easily be transmitted with an ssb transmitter or over telephone lines. Alternatively, the video tape can simply be mailed to the station at which the synthesis is to be performed. As long as the operator at the receiving end knows which frames represent the red, green and blue separations, it is possible to synthesize the color picture. Because of the many monitor and camera adjustments required during synthesis, it is not practical to attempt it in real time (e.g., as the pictures play out from a ssb transmission).

sstv color synthesis

In direct-write synthesis, a 33 mm camera loaded with high-speed color film such as Ektachrome (ASA 160) is mounted rigidly in front of the sstv monitor; a suitable close-up lens is used on the camera. The room should be dark and if a yellow or orange filter is used on the crt face for normal viewing, it should be removed. A single "red" frame is exposed through the red filter, a "green" frame is exposed through the green filter and a "blue" frame is exposed through the blue filter (without advancing the film). The final composite picture will be an excellent rendition of the original color object if the procedure was done with reasonable care.

Polaroid Polacolor has been used for direct-write color synthesis, but because of its slower speed, a large number of exposures must be made through each of the primary-color filters. Because of sync jitter, however, an unavoidable loss of detail results from superimposing a large number of sstv pictures. The advantage of Polacolor, of course, is the ability to rapidly see the results.

summary

This, in very short form, is the story on slow-scan tv, one of the more challenging areas in amateur radio today. Even if you

never decide to try it, you will know what's going on when you run into it on the amateur bands. Interested amateurs are invited to check into the slow-scan net (14230 kHz, 1900 gmt on Saturdays), or you can just listen in to hear what it sounds like. Don't hesitate to make tape recordings, for all slow-scan stations are interested in how their pictures look and will provide comments and sometimes photos of the picture readouts if you send them the tape. Three and three-quarter ips is the speed most commonly in use for tapes, and most stations can handle this speed. Finally, don't hesitate to write if you have questions or problems. Slow scanners are a friendly bunch and welcome all interested parties. Join the fun, and see what the fellow at the other end looks like for a change!

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Readers who want more information about slow-scan television will be interested in *ATA International*, the international English language edition of the Amateur Television Association; \$3.00 per year from Willy P. Everaert, ON4WM, Park Ten Hove, 97 Melle, Belgium.

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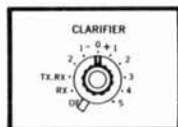
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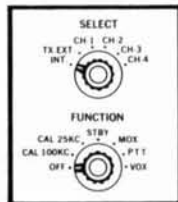
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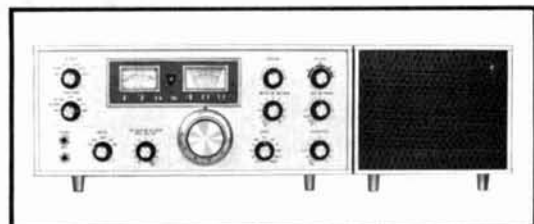


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notes on directional swr indicators

Much has been written on the subject of reflectometers (sometimes called directional watt or power meters, relative power meters, etc.) yet considerable misunderstanding of these basically simple devices still seems to exist; fallacies are often overheard on the air and even seen in print. I hope the following notes will help to clear up the more common misconceptions.

some basic facts

All directional instruments, from the least expensive relative-reading units to the most costly absolute meters, have one fact in common: both forward and reverse powers are measured, and the combination is used to determine the standing-wave ratio. Each instrument is set up for a particular **resistance**, which is often erroneously called impedance. Any swr indicated by (or calculated from) the meter readings is a measure of the impedance present at the output terminal of the instrument relative to its design resistance. Note that the impedance of the power source on the input side of the meter has absolutely no bearing on the measurement.

If you put a 100- or a 25-ohm resistor across the output terminals of your 50-ohm swr meter, it will indicate 2:1. However, there are an infinite number of resistance-capacitance and resistance-inductance combinations which **also** produce an indication of 2:1. The standing-wave ratio is not a measure of the nature or magnitude of the impedance, but rather of the quality of the

match to its design value—or the severity of the mismatch.

transmission-line impedance

The most common use of a reflectometer is to determine the swr of an rf transmission line. However, you can get meaningful results only when the characteristic impedance of the cable is the **same** design resistance of the reflectometer. When the characteristic impedance of the line is the same as the design resistance of the reflectometer, the swr indication will be the same wherever the reflectometer is placed in the transmission line as long as line loss is negligible. This is usually the case on the high-frequency bands with modern coax. When coaxial cable loss is not small, the swr indication will increase steadily as you move the instrument closer to the antenna.

If you must use your 50-ohm instrument in, say, a 90-ohm system, and you get a reading between 1.6 and 2.0, add a quarter wavelength of transmission line. If the reading does not change much, the actual swr is near unity.

For widely different indications the exact cable length has to be known or a large number of readings taken with different line lengths temporarily inserted to permit calculations of the true swr. When the instrument is moved toward the antenna in a line whose impedance differs from the instrument design value, the indications will change up and down although the **true** swr is the same at all points. This can be veri-

Walter Schreuer, K1YZW, Riverbank Road, Ipswich, Massachusetts 01938

fied by laborious computations or with an instrument designed for the particular cable impedance.

effect of power level

With the simpler types of reflectometers it is quite common to observe a lower swr with low power than with high power. Also, this effect is usually more pronounced at the lower frequencies where the meter is least sensitive. This is because the solid-state diodes which convert sampled rf voltages to dc to operate the meter exhibit a threshold effect: they require a minimum signal before rectification can take place.

This fixed threshold level is insignificant for the rf voltages used for measuring forward power, but it can result in erroneous reverse readings at low power levels. In fact, the results will be most nearly correct for high power levels. Unfortunately, this goes against the usual advice of using minimum power when tuning up antennas.

In the more costly instruments, sensitivity does not change with frequency, and the meter scale can be calibrated directly in watts. With these instruments it is possible to partially compensate for diode threshold by increasing the sensitivity of the reverse power indications over the corresponding forward power ones. Each compensation is correct for only one exact reverse power level (or swr value with one particular forward power), but it is a fair compromise for other levels and a lot better than no compensation at all.

As the designer of Comdel's DW1550 directional wattmeter I found no need for compensation above 50 watts forward power. I chose an swr of 2:1 with a forward power of 15 watts (full scale of lowest range) as the point of exact compensation. For swr measurements with forward powers between 15 and 150 watts (full scale of the next higher range), the effect of the compensation is reduced automatically by the variable resistor which is used to set the meter needle to full scale.

There is an amusing side effect to this method of compensation. When a drastic mismatch occurs, such as an open feeder—hopefully at low power—the reflected power

indication with its increased sensitivity will be larger than the forward reading. In other words, the instrument is overcompensated since the reverse power is much higher than the value of exact compensation. This peculiarity is of little practical consequence since in reality reverse power can obviously never exceed the forward power.

using the instrument

Most reflectometers absorb insignificant amounts of power and may be permanently left in the line unless the swr is exceptionally high. All instruments dissipate a small amount of power and may be subjected to damaging high voltages when using a full kilowatt input with a high standing-wave ratio. Manufacturers' data sheets seem to ignore this point; if you are in the habit of using high power with an swr greater than 3:1 you should ask the maker of your instrument for advice.*

When a directional instrument is permanently installed in the feedline, it makes a very useful monitor as well as a transmitter tuning aid. With an inexpensive relative-power indicator the sensitivity is different for each band, but a pointed knob on the sensitivity control with a mark for each band on the panel will overcome this effect. Absolute-reading instruments are more convenient, but they are at least four times as costly.

I invariably tune up my linear amplifier by forward power indication; an occasional check of plate current always shows it to be at or very near its proper value. On a few occasions in the wintertime, my swr meter has prevented possible damage to the linear in the early morning hours when it gave abnormal indications due to antenna icing.

When you are adjusting the matching of a new antenna, and you are sure of the quality and impedance of the feedline, the reflecto-

*The Comdel DW1550 will stand a 4:1 swr at 1.5 kW forward power continuously and higher values intermittently. The Collins 302 C3 wattmeter (and wattmeter in the 312B4) will stand 2 kW continuously at any swr. The Drake W4 and WV4 are limited by the full-scale reading of the meter movement. That is, the sum of the forward and reflected powers should not exceed 2000 watts; for 1500 watts input this occurs at an swr of 3:1.

meter may be located anywhere in the line. If you are not certain of your cable or are using a temporary one with a different impedance, then put the instrument right at the antenna. If this is impossible use an exact multiple of an electrical half wavelength between the antenna and meter.

When checking the load impedance seen by the transmitter, the reflectometer belongs right at the transmitter's output socket. Usually the swr will be the same at any other point in the outgoing rf cable, but if you have an external low-pass filter for tvI elimination as I do you may be in for some surprises on your highest frequency. This is because the more simple filter types show wide impedance variations near the cutoff frequency.

When building my 10- and 15-meter three-element quad, I observed the following readings at 29 MHz: 1.5:1 at antenna, 1.4:1 at the bottom of 100 foot RG-8/U cable, and 2.1 at the transmitter ahead of the low-pass filter. At 21.3 MHz the swr was essentially 1.2:1 at the same three points. As long as transmitter tuning and loading adjustments can deal with the increased swr caused by the low-pass filter, the impedance change is of no practical importance.

Antenna-tuning units are often used for resonating wire radiators or tuned feeders. In this case, the swr indicator belongs between the transmitter and the antenna-tuning unit so it can be adjusted to present the proper load to the transmitter. This can bring about a potentially dangerous condition. If the tuning is done for minimum swr, then the tuning unit may be mistuned so far that little power is transferred to the antenna. The same possibility holds when adjusting for maximum forward power. Only frequent checks of both will insure proper adjustment. Reflectometers with two separate meters are very helpful in this regard, as are instruments which can indicate a combination of forward and reflected powers.

I hope that this article will dispel some of the apparent mysteries surrounding directional instruments and will lead to their better utilization and understanding.

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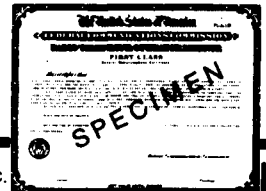
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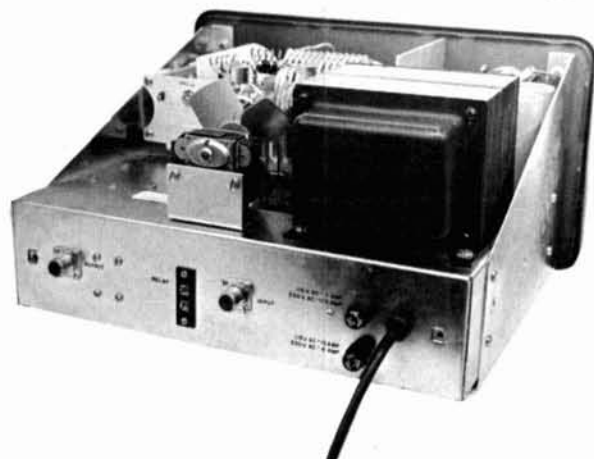
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meet the neat mnemonic

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There are a few individuals among us who are blessed with near-total recall. No event, number, face, name or whatever, seems to elude them. If you happen to be one of these fortunate people, this article isn't for you. But if you're like I am, then you need some kind of crutch to help you remember abstruse information which is absolutely essential in accomplishing a specific objective. The objective in this case is passing the amateur written examinations.

An interesting thing about memory is its specialization aspect. You might remember certain kinds of information extremely well and other kinds poorly or not at all. The trick to increasing your memory efficiency is to devise some method of coding the information you have trouble recalling in terms of information you can remember well. Such a device is called a mnemonic (pronounced with silent "m"). It is used by logicians, mathematicians, psychologists—even by digital computers.

There's a subtle trap lurking in mnemonic systems, though. When used in limited fields of high specialization they are quite useful. However, if applied to generalized situations, mnemonic coding tends to fall apart because of its unavoidable complexity and ambiguities. As a matter of fact, it's possible to devise mnemonics so far fetched as to defeat their very purpose: you can get to a point where you can't even remember the mnemonic for the mnemonic you're trying to remember (a bad joke, but my own). Used with care and a little thought, however, the system does work for special cases.

Consider now the newcomer to amateur radio. How can he possibly remember the deluge of equations, rules, concepts, and relationships required to pass the amateur written test? "Study," you say, and right you are! But how about helping him over the rough spots—at least until he gets to the point where, finally, the light begins to dawn?

I recall when I was first exposed to the mysteries of radio theory. (We didn't call it electronics in those days.) I took one look at the equation for resonance in a tuned circuit and thought, how am I ever going to remember this stuff? Then I flipped over a few more pages in the book and saw the equation for a damped wave (that's what comes out of a spark transmitter, youngster). I shuddered, buried the book under a stack of Captain Billy's Whiz Bangs and old Liberty magazines, then took off to see my old pal Ed, W6NHZ.

Ed was really a very astute fellow. After I explained my problem, he came up with some real help—in the form of mnemonics; only he didn't call it that. I doubt if the word was even in existence then. Anyway Ed said, "For openers let's look at Ohm's law for dc. The law was invented by George Ohm sometime in the early 1800's. If you can

Alfred Wilson, W6NIF, 3928 Alameda Drive, San Diego, California 92103

remember this basic equation you can solve almost any problem involving dc circuits. But don't ask me why old George assigned the symbol 'I' instead of 'C' to represent current. Possibly he did it to avoid confusion with capacitance, whose symbol is C."

I said, "Well, the symbols for voltage and resistance I can understand, because E represents electromotive force, and R is obviously for resistance. But why 'I' for current?"

Then Ed said, "I really have no idea. Maybe George had trouble remembering the equation himself. For one thing, you'll notice that E, I and R are in alphabetical order. Perhaps he chose this sequence of symbols in an attempt at helping to remember their relationship."

I said, "Okay. All this is fine, but meanwhile I gotta memorize all this junk so I can learn why. Incidentally, why **does** $E = IR$ anyway?"

Ed said, "Because it's the law, boy. Don't you obey the law?"

I said, "Sure, but how am I going to obey it if I can't remember whether $E = IR$, or $I = RE$, or $R = EI$?"

And now we come to the crux of the whole story.

"Okay," Ed said, "If you don't like $E = IR$, how about temporarily changing I to A (for

ampere)? If you can't remember $E = AR$ then you may as well give up. $E = AR$. . . get it? EAR? Them big flappy milk-wagon doors you hear with, old buddy."

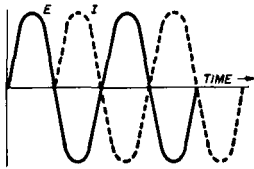
Then I said, "Yeah, yeah—I get it! In order to hear it with my ear, it's got to be changed to dc, right?"

I won't repeat here what Ed's reply was, but he got his point across, and for that I'll be eternally grateful.

So I went home and stared long and hard at all the equations, symbols, and other oddments that make up the basics of our hobby. I then devised a set of coded symbols to help me remember the necessities.

Some of the more basic mnemonics are listed below with their symbolic derivations. The list is by no means complete because of space limitations. However, enough material is included to get you started; then you can invent your own. I've also added some material on transistors to keep up with the changing world.

My mnemonic symbols suit me just fine, because they're personalized. Perhaps you have better ideas to adapt the mnemonics to your particular requirements. In any event, if I've provided no more than the initial push to help a new amateur get started, then this piece will have served its purpose.



$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

problem

1. Phase relationship between E and I

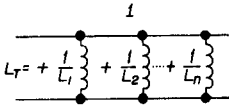
2. General equation for impedance

mnemonic

E is the reference. Across a pure inductance E leads I; across a pure capacitance E lags I. For X_L and X_C think: "+ X_{Leads} and - X_{Comes} after."

It's assumed you know Z contains R, X_L , and X_C . Impedance equals the square root of R squared plus the net reactance squared. Think: "Square Root of R squared plus (reactance) squared." From problem 1, + X_L leads; X_C comes after. This takes care of the second term under radical.

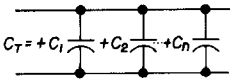
$$\frac{Z_p}{Z_s} = T^2$$



$$L_T = \frac{i}{\frac{i}{L_1} + \frac{i}{L_2} + \dots + \frac{i}{L_n}}$$

$$L_T = L_1 + L_2 + L_n$$

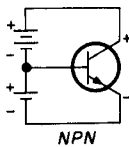
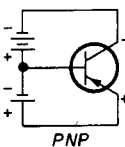
$$L_T = L_1 + L_2 + \dots + L_n$$



$$C_T = C_1 + C_2 + \dots + C_n$$

$$C_T = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \dots + \frac{1}{C_n}}$$

$$C_T = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \dots + \frac{1}{C_n}}$$



3. Impedance ratio of transformer windings

The transformer **primary** is the reference. The symbol resembles the equation. Let the equal sign represent the transformer core.

parallel and series elements

1. Combination of inductances in parallel.

Inductance and the numeral are the reference for parallel elements. The symbol resembles the equation. Think: "One over one over one Lth, plus one over one Lth, plus . . ."

2. Combination of inductances in series

The symbol resembles the equation. Think: "String of coils, L₁ plus L₂ plus . . ."

3. Capacitors in parallel

This is the exact opposite of the symbol/equation relationship of the reference mnemonic (inductance).

4. Capacitors in series

Same rationale as in problem 3

transistors

1. Direction of emitter arrow

The transistor **base** is the reference. For PNP, think: "Arrow **P**oints toward base:" **P** NP. For NPN, think: "Arrow does **Not** Point toward base:" **N** PN.

2. Element names

The emitter is the reference. Think: "Arrow emits" current from, or toward, the base. The other elements are then obvious by deduction.

3. Emitter and collector polarities with respect to the base

The polarities **must** be opposite. The **emitter** is the reference. For **PNP**, think: "Emitter **P**ositive." For **NPN**, think: "Emitter **N**egative." By deduction, the other polarities are obvious.

ham radio

photographic illustrations

for amateur radio magazines

Try these suggestions
when preparing photos
to go along
with your manuscript

The mass circulation, high quality magazines published in this country use photographic illustrations in great quantity. These photographs, especially product illustrations, are made by skilled professional photographers who work from layouts supplied by advertising agencies, the magazines, or the client advertisers. It is customary to ship the products to be photographed, at considerable expense, to the photographic studio chosen for this work. The photographer's fee is usually quite high. The manufacturer of the product pays for magazine space, agency fees, photographs, etc.

The amateur radio magazine editor's situation is different. He depends, in most cases, on the authors of technical articles for photographs to illustrate the subjects. Most of us have noticed otherwise excellent articles in some amateur radio magazines accompanied by mediocre photographs. The editor often has no choice but to accept the photos furnished by the author. He has deadlines to meet, space and layout problems, and must also be very cost conscious. The purpose of this article is to aid the amateur photographer in making photographs of acceptable quality for publication, using his own photographic equipment, and without the use of elaborate lighting setups.

It is of course impractical, due to space limitations, to delve deeply into the technical aspects of photography in an article such as this. Many different types of cameras are owned by amateurs. It is quite obvious that a view camera is ideal for illustrative photography. This type of camera makes possible such things as perspective correction, image size control, maximum control of depth of field, etc. It is also true, however, that few hams own this type of equipment. If you do, by all means use it. Regardless of equipment

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or technique, photographs for publication must meet certain minimum standards:

1. They must be **sharp**. A blurred or out-of-focus photograph cannot be improved in the making of the halftone negative for the printing plate.
2. They should be on glossy paper, with a uniform gloss over the entire print. Matte-finish prints or color prints should not be submitted.
3. They should have a normal range of contrast—the lightest and darkest areas of the print should show good detail. If this guideline is followed, a slightly "flat" print, or one with excessive contrast, can be corrected in the plate-making process.
4. The print should be somewhat larger than the illustration will appear in the magazine. About 5x7 inches is a good size, but smaller sizes can sometimes be used.
5. Underchassis or other views showing component placement and wiring should be lighted so that confusing shadows are eliminated.
6. Perspective distortion should be minimized. For example, a high-angle shot of a unit's front panel, made with a stan-

fig. 1. In photo A, below, the vertical part of the background is reflected on the top of the transmitter cabinet; the dark cloth in photo B, to the right, eliminates the reflection.



dard camera, will cause the bottom of the panel to appear narrower than the top. This effect is due to a diminishing perspective of the vertical lines, sometimes called "keystoning."

We will cover briefly some of the more important aspects of photo illustration including background, lighting, equipment and film.

background

The background against which a unit is photographed is of prime importance. The background most favored by professionals is white, seamless, heavy paper, available at photo supply or display supply stores. I normally use rolls of paper 9 feet wide and



10 yards long. However, some display stores stock 28x44-inch sheets of the same material which is more practical for the occasional user. For photographing a light colored chassis or other object, a somewhat darker background should be used. For some subjects, a

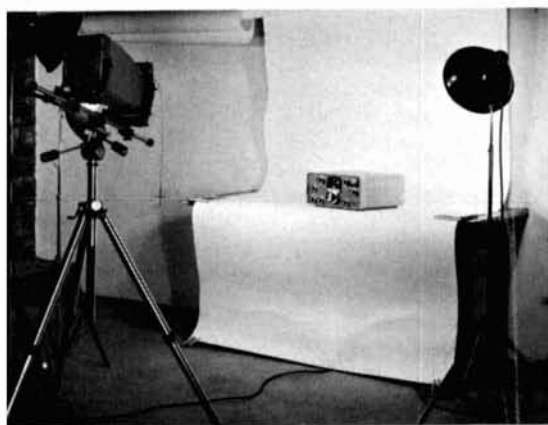
The author has been a professional photographer for many years. To lend authenticity to the methods detailed in the article, all photographs were made under the same conditions that might be found in the homes of amateurs who have an interest in photography. Commercial studio facilities were not used, and all film developing and printing was done by a custom photofinisher, as suggested in the article. **editor**

black background is ideal. The background should be large enough to extend well beyond the subject on all sides so that the editor can crop the picture to fit his format. When positioning a unit on a white background, first wipe the rubber feet with a damp cloth, followed by a dry one, to prevent "footprints" on the background.

It will be found that the vertical portion of a white background behind an equipment cabinet will sometimes cause an undesirable reflection in the cabinet top. This is illustrated in **fig. 1A**. A dark cloth, hung on the background so that its bottom edge is just outside the picture area, as shown in **fig. 1B**, will eliminate this reflection. This is a purposely exaggerated example but serves to il-

fig. 2. In this view-camera shot (right), all three planes of the unit are shown in correct perspective. The set-up is shown fixed photo-floods provide lighting.

spots) on reflective surfaces. Ideally, a high wattage spotlight would be used as a key light and floods would then be used as fill-lights. A study of advertising photos will reveal this widely used technique. However,



lustrate the point. The cloth must be cropped out in the published picture, so make sure it doesn't take up too much of the background.

lighting

Photoflood lamps in reflectors are the best all-around light source. Reflector-floods (lamps with built-in reflectors) are satisfactory. Floodlamps make it possible to study the lighting before exposures are made, thereby avoiding specular highlights (hot

this equipment is not available to the average ham so a good rule to follow when using floods is to use the minimum number necessary to do the job. This will minimize multiple shadows from knobs and other protruding parts of the unit being photographed. Refer to **fig. 2** for a photo made with a 4x5 view camera. The simple lighting set-up is also illustrated in **fig. 2**. Camera "swings" and "tilts" have been used to eliminate perspective distortion.

If photofloods are not available, a single low-wattage lamp can be used to make overall views, using the light-painting method discussed in "underchassis lighting."

underchassis lighting

A good technique for lighting cluttered areas to eliminate confusing shadows is to "paint" with light. With the camera on a tripod, focused, and the chassis properly positioned, the lens diaphragm is stopped down to the smallest opening, usually f.16, f.22, or on some cameras, as small as f.45. Incidentally, when focusing on a unit which

has considerable depth, the correct point on which to focus is about one-third of the distance from the front to the back of the unit. This is because the depth of field of a lens (the nearest and farthest areas which will be



fig. 3. Simplest method for "painting with light."

in sharp focus) increases as the lens is stopped down more rapidly on parts of the subject which are farthest away and less on areas which are closest to the camera.

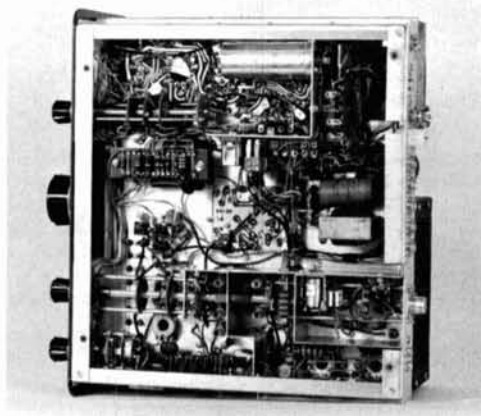


fig. 4A. Underchassis view made with fixed lights. Not bad, but "painted light" in fig. 4B is less confusing.

Set the shutter to **time** or **bulb**. In the latter case, a locking type cable release will be required. A low wattage (about 60 to 100 watt) lamp in a reflector at the end of an extension cord is used. If a reflector is not available, an 8-inch square of 1/4-inch styrofoam makes a good reflector and eye shield, or a piece of white cardboard may be used. See fig. 3 for a typical set-up.

Before opening the shutter, move the light to various positions to determine whether any areas of the subject have undesirable reflections. Avoid these positions of the light when making the exposure. Now, open the shutter and paint the light on the subject, using side-to-side, up and down and circular motions, keeping the light constantly in motion. Do not allow light to strike the camera lens; a lens hood is recommended. Room lights should be turned off.

The exposure time will depend upon lamp wattage, film speed and other factors. Typically, using Plus-X film and a 60-watt lamp, an exposure of about 3 to 4 minutes at f.22 should be about right. Subject brightness, lamp-to-subject distance and over-all technique will introduce some variables. A little experimenting will quickly give you the feel for this type of lighting. The basic reason for painting with light is, of course, to keep the shadows of wires and components mov-

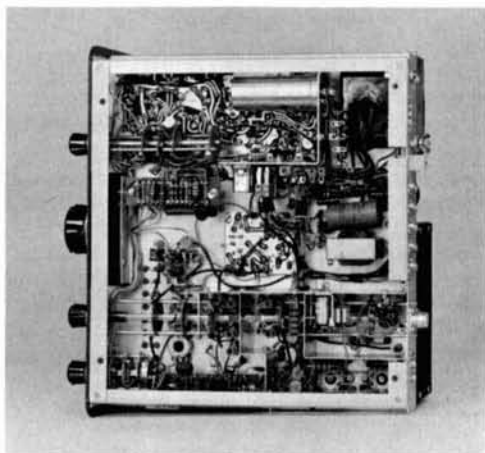


fig. 4B. Painted with light using a low-wattage bulb as discussed in the text.

ing so that no shadow will stay in the same place long enough to register sharply on the film—thus shadowless lighting. A fixed photoflood-lighted shot is shown in **fig. 4A** and for comparison, a painted-light photo made with a 60 watt lamp, in **fig. 4B**.

lighting by bounce flash

I have "painted" hundreds of commercial photographs where cluttered areas dictated such an approach, and this method is highly satisfactory. Another technique which gives good results on some subjects is to bounce the light from a flashbulb. For example, a chassis standing on edge or placed flat on the floor with the camera above it can be well lighted by this method. A large white card or movie screen positioned so that the light from a flashbulb can be bounced onto the subject will diffuse the light and produce a near-shadowless shot of the subject. Open-flash technique (open shutter, fire bulb, close shutter) is recom-

position will result in more even lighting. A bounce-light arrangement is shown in **fig. 5B**. The unit shown in **fig. 5A** was photographed by bouncing the light from three flashbulbs, each with the screen in a different position.

perspective correction

The transmitter in **fig. 2** was photographed with a 4x5 view camera. The front

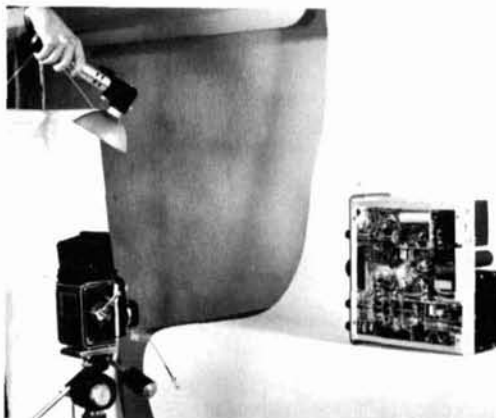


fig. 5B. Bounce-flash set-up using a movie screen.

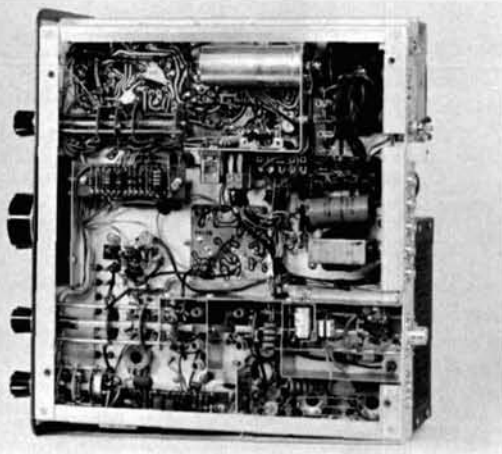


fig. 5A. Underchassis shot made with bounce flash.

ended. Camera diaphragm setting should be about two stops larger than if direct flash were being used. Direct flash on this type of photo is, of course, contraindicated. Moving the screen to two or more positions and bouncing the light from a flashbulb in each panel, right side and top are shown in correct perspective. A lens of 10-inch focal length was used. When using fixed lights, an exposure meter should be used. A 2 $\frac{1}{4}$ x2 $\frac{1}{4}$ twin-lens-reflex camera with a normal (80 mm) lens, and without the swings and tilts of a view camera, was used for **fig. 6A**. Perspective distortion is quite evident. This set-up is shown in **fig. 6B**. The improved perspective achieved, using the same camera, by shooting from a lower angle (keeping the film plane of the camera parallel to the transmitter's front panel) and from a greater distance, is shown in **fig. 7A**; **fig. 7B** shows the camera position. Thus, it is better to back up far enough to minimize perspective distortion and then make an enlargement to the desired size.

foreshortening

In addition to perspective distortion, another undesirable effect that results from

too-close use of cameras with standard focal length non-interchangeable lenses is foreshortening. This simply means that the part of the subject nearest the lens will be disproportionately large when compared with areas of the same subject which are farther from the lens. Example: portraits made too close to the subject will result in noses too large and ears apparently set too far back. Foreshortening and front-to-back keystoneing are



fig. 6A. Distorted view—standard camera positioned too close and too high.

evident in fig. 8. This shot was made with a 35 mm camera using a 50 mm lens. The same set-up was used for the perspective view in fig. 9A. Distortion is very noticeable. Camera position is shown in fig. 9B. Changing to a 105 mm telephoto lens, the camera was moved back to more than twice the distance



fig. 7A. Made with the same camera as fig. 6A. Improved perspective. Camera lower and camera-to-subject distance increased.

(see fig. 10B) with the greatly improved results seen in fig. 10A. The image size on the film was as large as that obtained with the 50 mm lens close up in a close-up position.

some notes on equipment

Many amateurs own 35 mm cameras. Good quality photographs from the small negatives produced by these cameras are more difficult to make than those from larger



fig. 6B. Camera position used in fig. 6A; note downward tilt.

sizes, such as $2\frac{1}{4} \times 2\frac{1}{4}$, 4x5, etc. However, by using fine-grain film, properly fine-grain developed and printed, high quality photographs can be made. It is interesting to note that a good 35 mm camera usually has a sharper lens than the larger cameras. The resolution of lenses used on larger cameras



fig. 7B. Correct camera position; note that film plane is parallel with front panel of equipment.

need not be as great, in general, as those used on 35 mm. A 4x5 negative need be blown up only two diameters for an 8x10 print, whereas the same size print from a 35 mm negative requires about seven diameters enlargement. If the 35 mm camera has interchangeable lenses, a medium telephoto

lens will yield pleasing results when making close-up shots of equipment.

A comment on print quality: the best 8x10 prints are made by **contact** printing 8x10 negatives. So it follows that one should, with any camera normally used by amateurs, get the largest negative image size possible consistent with good perspective as outlined in the foregoing text. This is especially true when using 35 mm.

Another camera in widespread use is the Polaroid. These cameras have the advantage of letting you see a finished print in seconds. However, most models have some inherent disadvantages so that the use of standard Polaroid cameras to photograph electronic gear is, in general, not recommended. One possible exception is the use of a Polaroid back on a view camera.

parallax

Some cameras have viewfinders which see a different field of view than that seen by the lens. The difference in these fields of view is called parallax. On distant subjects, this is unimportant. In close-up photography, compensation must be made. You have probably seen photos of people with tops of their heads cut off. Someone didn't take parallax into account! In close-up work, center the unit to be photographed in the viewfinder. Then, before shooting, move the camera up and possibly sideways, depending upon the location of the viewfinder, until the lens occupies the same position.



fig. 8. Foreshortening caused by camera being too close to subject; knobs appear canted outward and downward.

(100 mm to 135 mm) should be used when photographing equipment. I have read articles which stated, "the longer the lens the better". This is not true. A long telephoto lens invariably introduces an undesirable "telephoto effect" or flattening of the subject. Also, the depth of field of a medium telephoto will be greater at any f stop than that of the long telephoto. With any interchangeable-lens camera a lens of approxi-



fig. 9A. Made with a 35 mm camera, 50 mm "normal" camera.



fig. 9B. Camera position used for taking fig. 9A. Good image size but the camera is much too close.

film and developing

Most camera users probably have a favorite film. For what it is worth, I have found Super Panchro Press Type B to be an excellent all-around sheet film for commercial subjects. For 35 mm cameras, Plus X is recommended. Panatomic X is somewhat finer-grain, but Plus X, properly fine-grain developed, yields a somewhat more brilliant print with no objectionable graininess. For cameras using 120 film, Professional Plus X is a good choice.

If you don't do your own processing, try to avoid using "drugstore" photofinishing. This grade of work is generally not suitable for good reproduction. Most cities have custom photofinishers who do high quality work



fig. 10A. Made with 35 mm camera, 105 mm lens. Longer lens provides same image size as fig. 9A, but perspective is improved.

for professionals. Use their services, if possible; the additional cost is justified.

summary

To summarize, if you don't have a view camera, shoot as nearly level with the unit as possible (film plane parallel with front panel) to avoid perspective distortion. Incidentally, some degree of correction of converging lines can be made by tilting the easel when enlarging. Dimensions of the unit photographed can be indicated in the article. A rule may be included in the picture if desired, but place it so it can be cropped out if the editor doesn't want to use it. Place the light or lights so that pleasing illumination is achieved and hot spots are minimized

on reflective surfaces. Paint or bounce the light into cluttered areas for greater clarity. Get far enough from the subject to minimize foreshortening. It is much better to have a smaller, distortion-free image, which can be blown up, than it is to have a larger one that overemphasizes areas that are closest to the lens. Finally, make sure that the pictures you submit are **sharp**.

If you write descriptive matter for your photos to point out specific areas, do not in any case write on the photos. Instead, you should: a) write on a separate piece of paper and attach it flush with the bottom edge of the photo, using cellophane tape as a hinge; b) attach a tissue overlay to the print and write **lightly** with a soft pencil to prevent



fig. 10B. Camera position used for taking fig. 10A. Camera is slightly lower and film plane is parallel with the front panel.

scoring the print, or c) send a duplicate print on which you have indicated the areas to be emphasized.

Here's a final item often overlooked by amateurs who submit photos to editors. Your high quality pictures are useless if they arrive at the editorial offices bent and cracked. Make a sandwich for your photos by cutting two pieces, large enough to extend at least a half-inch beyond the edges of your prints, from a corrugated carton. Tape the edges of the corrugated board so the photos can't shift in handling. Most photo supply houses also carry photo mailers which are ideal for the purpose. Happy shooting!

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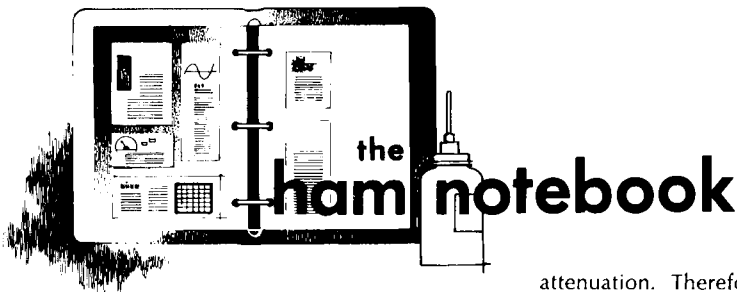
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from the Old Man himself.

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32S-1 cw modification

The 32S-1 as originally designed uses a 2.1-kHz-bandpass mechanical filter centered on 455 kHz and two bfo crystals, one above 455 by 1350 Hz and one 1350 Hz below, operating on 456.350 and 453.650 kHz respectively.

In cw operation, a tone oscillator at 1350 Hz is fed through the mike amplifier, balanced modulator and mechanical filter to create a cw carrier. The carrier is at 455 kHz in the low i-f by virtue of the relationship of the bfo crystal frequency (456.350 kHz) and the modulating frequency of the tone oscillator (1350 Hz) so that $456.350 - 1.350 = 455$ kHz.

The quality and stability of the diodes available at the time the 32S-1 was designed and manufactured was far below those available today. It is difficult to maintain carrier suppression better than 50 dB over a long length of time with the original components and circuitry. However, a very easy alternate method of vastly increasing carrier suppression is possible.

A 457.55 kHz crystal* is stocked for those amateurs who operate RTTY using a 2125/2975 tone keyer; this places the audio response between 1500 and 3600 Hz. Of specific importance is the fact that the crystal is removed from the skirt of the mechanical-filter bandpass by 1500 Hz rather than the normal 300 Hz, so an additional 40 to 50 dB carrier suppression is obtained. The 1350 Hz tone oscillator no longer puts the "carrier" at 455 kHz, and its second harmonic could pass through the mechanical filter with little

attenuation. Therefore the tone frequency must be raised to, ideally, 2550 Hz ($457.55 - 2.550 = 455$ kHz).

Refer to the 32S-1 schematic diagram. Locate switch S8F, just below V2B, the 6U8A bfo tube, and to the right of the tone oscillator. The upper sideband crystal, Y15, is shown wired to the most clockwise position (cw); a jumper goes to the adjacent contact, which is the usb wiper, and to the **tune** and **lock-key** wipers. The jumper should be removed so that Y15 is connected to the usb wiper only. The jumper from the **tune** and **lock-key** wipers should be connected to the cw wiper. Do not solder yet, as the new 457.55 kHz crystal should be connected between the cw wiper and pin 3 of V2B (the pin where the other crystals are connected).

To raise the frequency of the tone oscillator, C111 should be changed from its present value of 430 pF to 220 pF, and C110 should be reduced from 390 pF to 180 pF. The exact frequency of 2550 Hz might not be realized but the resultant frequency is sufficiently close to meet requirements.

Those amateurs who have operated modified 32S-1's report that they don't object to the higher pitched sidetone, although many use the sidetone from their electronic keyer so the frequency difference is not a consideration. After this modification, carrier suppression should be on the order of 80 dB. This is sufficiently below the white noise output to be undetectable. On-the-air reports have been excellent.

* The 457.55 kHz crystal is available from the Collins Radio Company, Cedar Rapids, Iowa 52406. Order part number 290-8708-000; \$5.50 plus sales tax, postage and insurance. The price is subject to change at any time without prior notice.

painless vox keying

The convenience and speed of vox keying is well known by those who have this feature in their transmitter or transceiver. With this method, changing from receive to transmit mode occurs at the first touch of the key, which activates the vox circuit normally used on phone. A recently purchased transceiver, while excellent in many other respects, didn't have this feature. So I incorporated the keying method shown in **fig. 1** to provide vox keying. It also has other possible uses.

Before using this method with your equipment, you should determine what additional modifications are necessary. The following conditions must be met.

1. The speech amplifier must be disconnected from the vox input or its power supply when the transmitter is placed in the cw position.
2. The vox circuit must remain in operation with the transmitter in the cw position.
3. The vox relay must control the same circuits as the cw operate switch.

If all these conditions are met, all that's necessary is to connect the keyed audio to the microphone input, place the operate switch in vox position, and go ahead.

Grid block keying was used in the original circuit. A -180 V line was used to cut off the driver stage during standby. The -180

V line was shorted directly to ground by the key. This made it difficult to use the same contacts to operate other circuits. In **fig. 1**, a silicon controlled rectifier replaces the key contacts, and a positive-gate turn-on voltage is keyed. This removes the shock hazard and provides a keyed source of low voltage to turn on other circuits.

The audio oscillator module is a small code-practice type available at most amateur equipment dealers. The speaker is a tiny 8-ohm transistor radio replacement. Your junk box might provide a phase-shift or unijunction oscillator.* However, at the price of the code-practice module, constructing one would hardly be worth the effort.

R. J. Beck, VE7IG

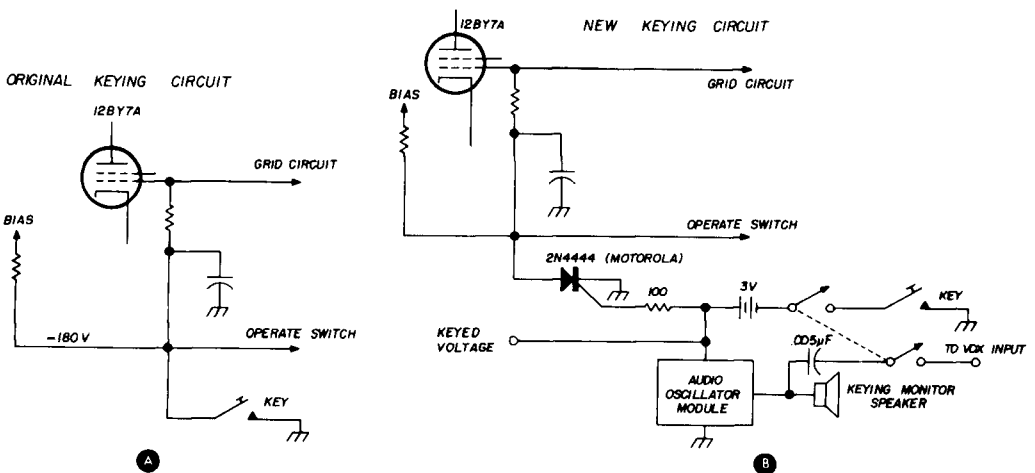
qsl and awards file

You can easily get old wallpaper sample books from stores that sell wallpaper. These are bound books with hard covers, large enough for awards and certificates or several QSL cards. When preparing the book I use, I removed every other page, then sprayed the covers and page edges with gold paint. The certificates and QSL cards can be tacked in with one of the plastic adhesives, and are easily removed if desired.

Don Farrell, W2GA

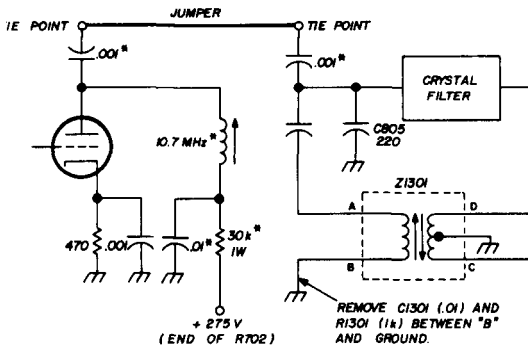
* E. R. Davisson, K9VXL, "Replace One Unijunction Transistor with Two Transistors," *ham radio*, April 1968, pp. 58-59.

fig. 1. Original vox keying circuit, A, and new circuit, B.



update your Swan 250

The new Swan 250C has quite a few improvements over the older model 250. These include higher gain and better selectivity. Strong signals are handled much better by the new model. You can improve these characteristics in your 250 Model with a few simple circuit changes. You can also easily install the Swan noise blanker.



*ADDED COMPONENTS

fig. 2. Circuit changes for higher gain and improved selectivity in the Swan 250.

Fig. 2 shows the circuit modifications. Remove the top and bottom covers, and remove the 2-inch wire from pin 5 of V7 (6HA5). Remove resistor R1301 (1 kilohm) and capacitor C1301 (.01 μ F) from terminal "B" of Z1301 balanced modulator transformer. Ground terminal "B". Add a single tie point near pin 5 of V7 and one near terminal "A" of Z1301. Connect a 0.001- μ F capacitor from one tie point to pin 5 of V7; install another 0.001- μ F capacitor from the other tie point to the input of the crystal filter. Install the slug-tuned coil, the 0.01- μ F bypass, and 30 kilohm resistor in the plate lead of the 6HA5 as shown in the schematic.

Add a short jumper wire between the two new tie points you installed next to V7. If you wish to install the Swan noise blanker later, you can remove the jumper and put the blanker between these two points. When all the new parts are installed, align the

front end and i-f as outlined by the manuals. Be sure to carefully peak up the new 10.7-MHz coil and the slugs in Z1301.

Harold D. Mohr, K8ZHZ

miniature sockets

Many MARS members have been receiving miniature vacuum-tube sockets. These sockets have 8 holes with one empty space so it's quite evident which contact is number 1. These sockets are ideal for 6- or 8-pin integrated circuits or 6-pin transistors.

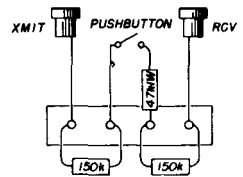
James T. Lawyer

spot switch for the heathkit sixer or twoer

A momentary pushbutton switch and a one-watt, 47k ohm resistor are all that are needed to put a spot switch on the sixer or twoer.

The resistor is in series with the switch, and they are mounted across the two middle terminals of the terminal strip behind the neon lights. Fig. 3 shows the connections.

fig. 3. Spot switch for Sixer and Twoer. Pushbutton switch and 47k resistor are mounted across two middle terminals of strip behind neon lights.



This puts about 50 volts on the B+ line to the driver stages of the transmitter when in the receive position. This is enough to get a carrier indication. The final doesn't draw current, because the cathode is open until the transmit switch is operated.

The resistor drops 210 volts at a measured 5 mA. The dissipation is one watt. Because it's not on for any length of time, I used a one-watt resistor without allowing for safety factor.

Edmond DeCloedt, WA6FNR

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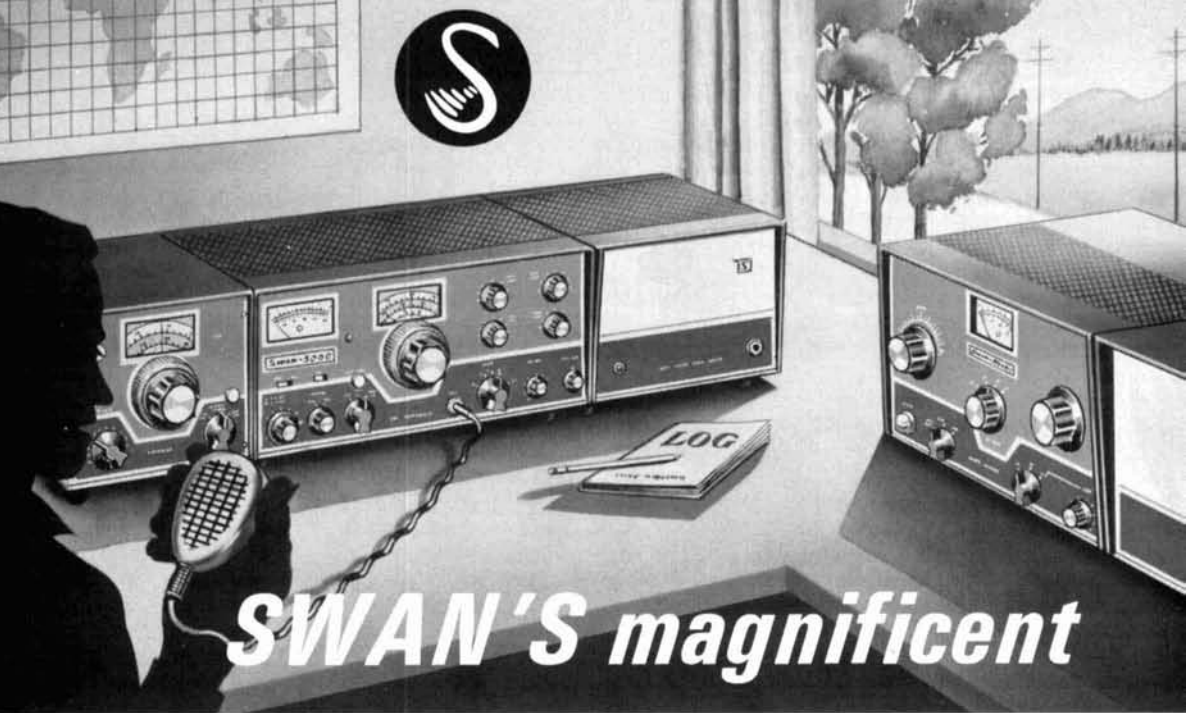
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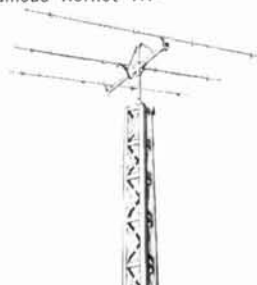
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 SX100 Rcvr 95
 SX101 Mark III 139
 SX140 Rcvr, (Novice) 59
 S120 SWL Rcvr 20

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 HQ129X Rcvr 79
 HQ 170 Rcvr, Very Clean 150
 HQ170/VHF 2Mtrs, Clean 265
 HQ170/180 Noise Blanker 35

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 HAM TV Complete 235
 SB2LA Linear, Like New 189

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 MR1&MT1 Combo, Works OK 75
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JOHNSON

Johnson KW Match Box 95
 Johnson Ranger II 125
 Johnson 6&2 Converter 29

NATIONAL

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 NCL2000 Linear 325
 NC183D Rcvr, Clean 139
 NCX3, Very Clean 150
 NCX AC Supply 59
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 260 Displayed, New 379
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 VHF 126 RME 39
 Clegg Apollo 6 Lnr 165
 Heath HW17 2Mtrs 99
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 Johnson 223 Reg 209
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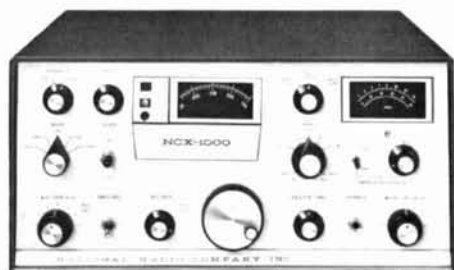


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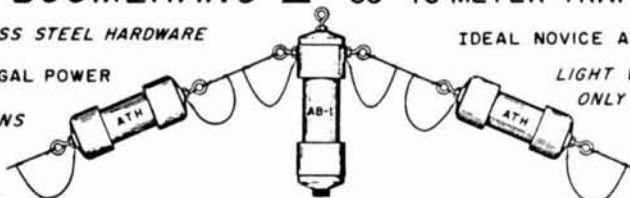
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THE FOLLOWING LISTED US GOVERNMENT EQUIPMENT has been reported missing from the First US Army MARS Station, A3USA (W3USA), Fort George G. Meade, MD 20755: Transceiver, Collins, KWM-2A, Serial #15513, Power Supply, Collins, 516F-2, Serial #23397, Linear Amplifier, Collins 30L-1, Serial #69, Crystal Packet, Collins CP-1, Collins part number 597-040-00. Request person possessing information leading to the location of this equipment, contact the First US Army MARS Director by writing to: Headquarters First US Army, ATTN: AHACE-PT, Fort George G. Meade, MD 20755 or telephone collect to: 301 677-3316 or 677-3858.

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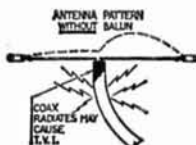
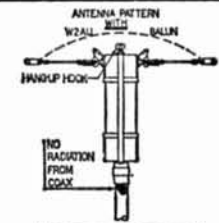
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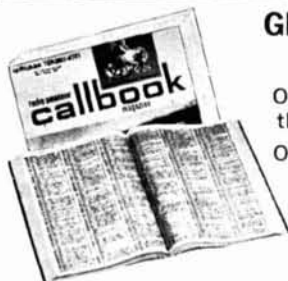
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High performance 9 MHz xtal filters for SSB, FM, AM & CW applications. Perfectly suited for miniaturized solid-state equipment.

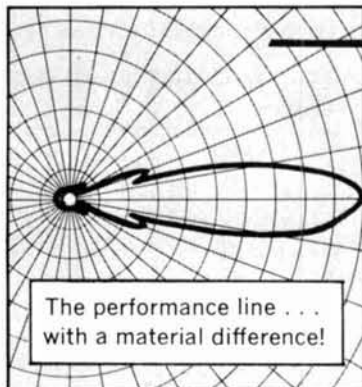
Size 1 - 27/64" x 1 - 3/64" x 3/4".

Filter Type	XF-9A	XF-9B	XF-9C	XF-9D	XF-9E	XF-9M
Application	SSB-Transmit.	SSB	AM	AM	FM	CW
Number of Filter Crystals	5	8	8	8	8	4
Bandwidth (6dB down)	2.5 kHz	2.4 kHz	3.75 kHz	5.0 kHz	12.0 kHz	0.5 kHz
Passband Ripple	< 1 dB	< 2 dB	< 2 dB	< 2 dB	< 2 dB	< 1 dB
Insertion Loss	< 3 dB	< 3.5 dB	< 3.5 dB	< 3.5 dB	< 3 dB	< 5 dB
Input-Output	Zf	500 Ω	500 Ω	500 Ω	1200 Ω	500 Ω
Termination	Cf	30 pF	30 pF	30 pF	30 pF	30 pF
Shape Factor	(6:50 dB) 1.7	(6:60 dB) 1.8 (6:80 dB) 2.2	(6:60 dB) 1.8 (6:80 dB) 2.2	(6:60 dB) 1.8 (6:80 dB) 2.2	(6:60 dB) 1.8 (6:80 dB) 2.2	(6:40 dB) 2.5 (6:60 dB) 4.4
Stop Band Attenuation	> 45 dB	> 100 dB	> 100 dB	> 100 dB	> 90 dB	> 90 dB
Price	\$19.95	\$27.50	\$29.50	\$29.50	\$29.50	\$20.95

Matching HC-25/U crystals: 8998.5 (USB), 8999.0 (BFO), 9000.0 (carrier), 9001.5 (LSB), \$2.50 each.

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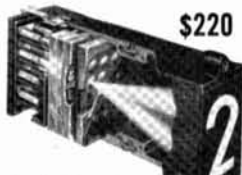
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2 6x9"	"	"	"	"
4 4 1/2 x 6"	"	"	"	"
6 3x4 1/2"	"	"	"	"

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- 100 CFM muffin fan, by ROTRON. 115v. 60 cycle, 14 watt. $4\frac{3}{8}$ " square. $1\frac{1}{2}$ " deep. 2 lbs. BRAND NEW **\$8.50 ea.**
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- As above, with feet attached. 1 lb. **6/\$3.25, 60¢ ea.**

MORE OVERSTOCK, Year End Clearance

- 8.8 hry, 50 ohm, 500 ma. 6430 WV (9000v peak) cased. $7''$ x $5''$ x $7''$ high, + 1" ceramic terminals. 35 lbs. **4/\$25.00, \$6.50 ea.**
- 15 mfd. 100v. oil filled, CP70. $3\frac{3}{4}''$ x $3\frac{1}{4}''$ x $4\frac{3}{8}''$ high + $\frac{3}{8}''$ terminals. 4 lbs. **6/\$8.50, \$1.50 ea.**

MORE Variable Capacitor Close-Outs

- HAMMARLUND MC type, straight line frequency 250 pf. max. **4/\$4.75, \$1.25 ea.**
- HAMMARLUND MC type, straight line freq. 8-50 pf. **6/\$5.75, \$1.00 ea.**
- 5-20 pf. MC type, straight line capacity. 3 plate. **6/\$2.75, 50¢ ea.**
- Dual 3-15 pf/sec. with coil. 6 turns. tapped at $1\frac{1}{4}$ & 3 turns, tunes 140 to 300 MC. Ceramic end plates $1\frac{1}{2}''$ sq. **6/\$5.75, \$1.00 ea.**

MORE Meter Close-Outs

- 0-1 MA DC $2\frac{1}{2}''$ sq. wide view plastic. White figures on black background. Has 5000 ohm internal resistor. Scales: 0-10, 0-100 MA, 0-500 output. **\$2.50 ea.**
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We bought a large quantity of Tachometer meter movements and dials as shown, and while we were wondering how to sell them, one of our customers showed us some ingenious Tachometers he developed, using this meter movement. We bought the designs and are offering them to you as kits of electrical parts only, which we are selling at far below the price of the meter alone.



KIT 1 — Tachometer and dwell meter, operates from distributor of 4, 6 and 8 cylinder engines. Transistorized. **TK1 \$5.00 ppd.**
KIT 2 — Outboard motor, engine tachometer. Simply hold wire lead near spark plug wire and pulses are picked up and registered. Works on 2 or 4 cycle 1, 2, 4, 6 or 8 cylinder engines. Transistorized. **TK2 \$12.50 ppd.**
KIT 3 — Photo electric tachometer. This is very ingenious. Point the pickup head at propeller of model airplane, or other rotating parts and meter registers RPM by measuring frequency of interrupted light. **TK3 \$12.50 ppd.**

TRANSISTOR POWER SUPPLIES



Left illustration — Technipower 20-24 volt 3.0 ampere variable supply size 6 1/2" x 7 1/2" x 5" approx. Removed from new equipment. Last price \$180.00. **Tech P.S. 1 \$27.50**
 Same spec's as above except 6.0 amperes, size approx. 8" x 9" x 6". **Tech P.S. 2 \$47.50**
 Right illustration — Sola constant voltage regulated supply, 15 volts at 15 amperes, unused, but may have slight rust spots which will not impair electrical performance. **SCVPS15 \$37.50**
 Same spec's but 15 volts, 10 amperes and 5 volts, 15 amperes outputs. **SCVPS155 \$49.50**
 Not illustrated — Atlas controls +12 volts at 50 amperes and -52 volts 10 amperes variable ±15%. Size 18" x 7 1/2" x 10", about 75 lbs, with Buss bar connections on one end. Only four available. **ACPS \$60.00**
Power Supplies Shipped Freight Collect

SCVPS15 \$37.50

SCVPS155 \$49.50



TANTALUM CAPACITORS

Buy these brand new Tantalum Capacitors for less than the price of equivalent aluminum foil units, and get high reliability, infinite life, small size,

and high temperature performance in the bargain. The regular price of these units is from 10 to 20 times our low price.

Left..... 25 MFD @ 180 Volts **\$1.75 ppd.**
 8 MFD @ 270 Volts **\$1.50 ppd.**
 Center..... 3.9 MFD @ 75 Volts —
 Feed Thru **3/\$1.00 ppd.**
 Right..... 400 MFD @ 75 Volts **\$2.00 ppd.**
 1000 MFD @ 50 Volts **\$3.00 ppd.**
 Middle..... 26.5 MFD @ 30 Volts,
 Non polar **\$1.00 ppd.**
 Bottom..... 2 MFD @ 100 Volts **3/\$1.00 ppd.**
 1 MFD @ 75 Volts **4/\$1.00 ppd.**

PRINTED CIRCUIT CARDS

Make your own printed circuit cards. We provide a 4" x 5" double copper clad card and an 18 pin connector (used). **ECPCB \$1.00 ppd.**

UNIVERSAL LOGIC CIRCUIT CARDS



Instant
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 for
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 TO-5
 or
 14 lead
 dual
 in-line



INTEGRATED CIRCUITS

These boards are the most useful items we have ever offered for breadboarding with low cost integrated circuits. The cards are made from 1/16" G-10 Glass Epoxy, with pads for 14 lead dual inline mounting pads on one side and 10 lead TO-5 pads on the other. 8 lead TO-5 cans will mount in the 10 lead TO-5 pads also. Discrete transistors and components can be mounted in the locations between the I.C.'s power supply leads are already routed around the board. Our competitors charge \$9.50 each for circuit card and mating connector. We give you a surplus, unused p.c. board with components on it (that you can keep for your junk box), a connector and its mate, and our great circuit card. You drill out the desired hole pattern, unsolder the connector from the surplus card and install it on the new card, wire in the I.C.'s and compute. A few minutes of your time, and you save over 80% of the cost of comparable p.c. cards. Get enough for your breadboarding needs now because these are going to go fast.

2 Cards & mating connectors 2 IC's **\$ 2.50 p.p.**
 10 Cards & mating connectors 10 IC's **\$10.00 p.p.**
 100 Cards & mating connectors 100 IC's **\$88.00 p.p.**

EXPOSURE METER CONTROL

2/\$2.00
 This little unit lights up a lamp when illumination is below predetermined threshold. Contains high sensitivity CDS photodetector, transistor, potentiometer, lamp and relay. About the size of a quarter. May require relay adjustment to work properly. Complete with circuit applications and design data information. **EMC 2/\$2.00 ppd.**



LARGER SIZE BOARD 3" x 4"



Circuit on one side only, with space for more components. Same connector and salvage board as above provided.

CB8T05 — Pattern for nine 8 pin TO-5 cans, (shown) order #CB8T05 — (quantity ordered)
CB8DIP — Pattern for nine dual-in-line I.C. packages (shown) order #CB8DIP — (quantity ordered)
CBFP — Pattern for nine flat packs, order #CBFP — (quantity ordered)
CB10T05 — Pattern for nine 10 pin TO-5 cans, similar to our ILCB style, order #CB10T05 — (quantity ordered)
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BARGAINS WHICH THE ABOVE WILL POWER:

LM-(*) Freq. Meter: .125-20 MHz, .01%, CW or AM, with serial-matched calib. book, tech. data, mating plug. Checked & grtd. **57.50**
 TS-323 Freq. Meter: Similar to above but 20-480 MHz, .001%. With data **169.50**
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 A.R.C. R22: 540-1600 KHz w/tuning graph **17.95**
 A.R.C. R13B: 108-132 MHz w/tuning graph **27.50**

HI-SENSITIVITY UHF RECEIVER:

375-1000 MHz. Stoddart RFI Meter NM-50A with pwr. sply., cords, dipole holder, 3 pair dipoles. Input 50 ohms. IF 60 mhz. Bandwidth 1 mhz at 370 and 1.8 at 1 ghz RF. Image & spurious-response reject, better than 40 db. Sensit. as a 2-terminal tuned voltmeter is 10 uv; will be less with 1-pair dipole, but you can make an array to bring it up. If the voltage-attenuation calib. charts didn't get lost it would be worth \$1,250 in surplus, \$2,852 from the factory . . . so we will sell it as a simple receiver in grtd-excel. condition for only **275.00**

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Double-conversion version of the popular R-45; cascode input ckt; 550 khz to 43 mhz. With pwr sply, ready to use, OK grtd **190.00**

R-390 / URR RECEIVER

Two coming in, checked 100% perfect & grtd, with books. SUBJECT TO PRIOR SALE! Each **795.00**

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Depot Spares for SP-600-JX: Pri. 95/105/117/130/190/210/234/260 v 50/60 hz. Sec. 1: 305-0-305 v, 150 ma. Sec. 2: 5v, 3A. Sec. 3: 6.3 v, 5 A. Sec. 4: 7 1/2 v, 3/4 A. Sec. 5: 7 1/2 v, 1 1/4 A. Legend for pins is plainly marked. Herm. sealed. **2.95**

FOUND! A NEAT & COMPACT SCOPE XFRMR!

Freed 12691: DAS Loran Spares, supplied 5" CR, plates & htrs. Pri. 105-130v 50/60Hz. Sec's. insul. 5 kv; 1490 & 1100 v, 5 ma; 390-0-390 v 100 ma; electrostatically-shielded 6.3 v, 0.8 A; two 2 1/2 v, 2 A. Sec's insul. 1 1/2 kv; two 6.3 v, 6 A; 5 v, 3 A; 2 1/2 v, 5A. Case 5 1/4 x 5 x 7 1/4. With diagram. **2.95**
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WANTED by FBI



BENJAMIN HOSKINS PADDOCK

BENJAMIN HOSKINS PADDOCK, also known as Perry Archer, Benjamin J. Butler, Leo Genstein, Benjamin Hoskins, Jr., Ben H. Paddock, Jr., Benjamin Hodgins Paddock, Benton Hoskins Paddock, Pat Paddock, Patrick Benjamin Paddock, "Big Daddy," "Chromedome," "Old Baldy". FUGITIVE, ESCAPED FEDERAL PRISONER. IDENTIFICATION ORDER NUMBER 4261.

Benjamin Hoskins Paddock is being sought by the FBI for violation of the Escape and Rescue Statute.

On December 31, 1968, Paddock escaped from the Federal Correctional Institution at La Tuna, Texas.

A Federal warrant for his arrest was issued on February 3, 1969, at El Paso, Texas. Paddock has been arrested numerous times for bank robbery. He has been convicted of bank robbery, automobile larceny and confidence game.

Paddock's personality has been diagnosed as being psychopathic, egotistical and arrogant. He is reputed to be a very smooth talker, an avid bridge player, and a stock car and baseball enthusiast. Paddock has been employed as an automobile mechanic, electrician, promoter, salesman, service station operator, clerk and welder. He was formerly licensed as K7JH and might be known to readers of this magazine. Paddock has utilized firearms in the past and should be considered extremely dangerous.

DESCRIPTION OF BENJAMIN HOSKINS PADDOCK

Born, November 1, 1926, Sheboygan, Wisconsin. Height, 6'4". Weight, 245 pounds. Build, large. Hair, blond, balding (head may be shaved). Eyes, gray or green. Complexion, medium. Race, white. Nationality, American. Scars and marks: scar over right eyebrow, vaccination scar upper left arm, scar over right knee, birthmark right ankle. Remarks: may wear glasses or contact lenses. Social Security Number used: 340-18-9361.

If you know anything about this man contact your local FBI office.

5 LEVEL TAPE READER

Made for teletype use but we have been advised they are just as useful for other methods of data transmission when tied in with computers. Removed from used equipment. Last time offered, they sold out in one advertising.

order TAPE READER \$15.00



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Corning glass, direct traverse type, min. Q at max. C—500 at 50MC. 500 volt breakdown. Capacitance range 1-8 uufd. Brand new military surplus 3 for \$1.00 or \$3.00 per doz.

A selection of unusual & normally high priced IC's, all factory fresh, guaranteed, with sheets. Limited quantities.

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4 x 4 matrix, 4 inputs "X", 4 inputs "Y", Dual inline package #AACVI \$2.75

FOUR 3-INPUT "AND" GATES, "OR'D" TOGETHER, BUFFERED & INVERTED

Dual inline package #AAAB3 \$1.75

SYNCHRONOUS RICELESS FLIP-FLOP

may be converted to most any flip-flop mode (R-S, D, J-K, etc.) 4 separate 2-input AND gates, "OR'd" together & fed to universal flip-flop. Dual inline package #AAFLI \$3.00

DUAL 4-INPUT GATE W/EMITTER FOLLOWER RESISTORS

Dual inline package #F1116 \$1.00
12 for \$10.00

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Similar to Fairchild SH2001. Dual 2-input gate w/amp. 14 pin dual inline ceramic package. #SHO-579 \$2.25

TUBES TUBES TUBES TUBES

Used, guaranteed OK condition.
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813 5.00
6146 2.00

2N706A HI-FREQ. TRANSISTORS

First line factory marked. 400 mc, 15 volt, NPN #2N706A 3 for \$1.00

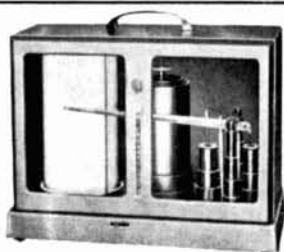
SAPPHIRE ROD

Pure sapphire rod, 1 inch long x 1/16 diameter polished each end and sides. Cuts glass, used for bearings, end-window for UV or IR, etc. \$1.25 each

FIBRE OPTICS KITS WITH IMAGE TRANSMITTER

An experimenters delight, fantastic display of the unique properties of clad-fibre-optics to pipe light as well as images. Kit #1 includes PVC sheathed bundle of glass fibres with polished ends (light pipe), bundle of plastic fibre optics, bundle of glass fibres, coherent light pipe (transmits images), instructions & experiments. BLISS-FULL PAK #1 \$5.00

Kit #2 includes all of the above but more fibres, longer lengths, fatter bundles and also includes light source, heat shrink tubing, a 5 ft. light pipe, a longer coherent bundle (image transmitter) & more experiments. BLISS-FULL PAK #2 \$10.00



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Surplus U. S. Air Force Bendix-Friez recording barograph. The standard instrument for U. S. Weather Bureau, armed forces,

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946 DTL 4 2-input NAND/NOR gate	2/1.00
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1M5 Dual 4-input logic gate	2/1.00
7M6 6 NPN transistors in one package, gen. use	3/1.00
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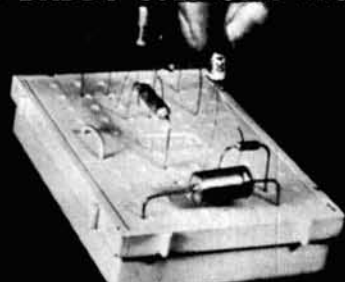
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index to volume II—1969

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