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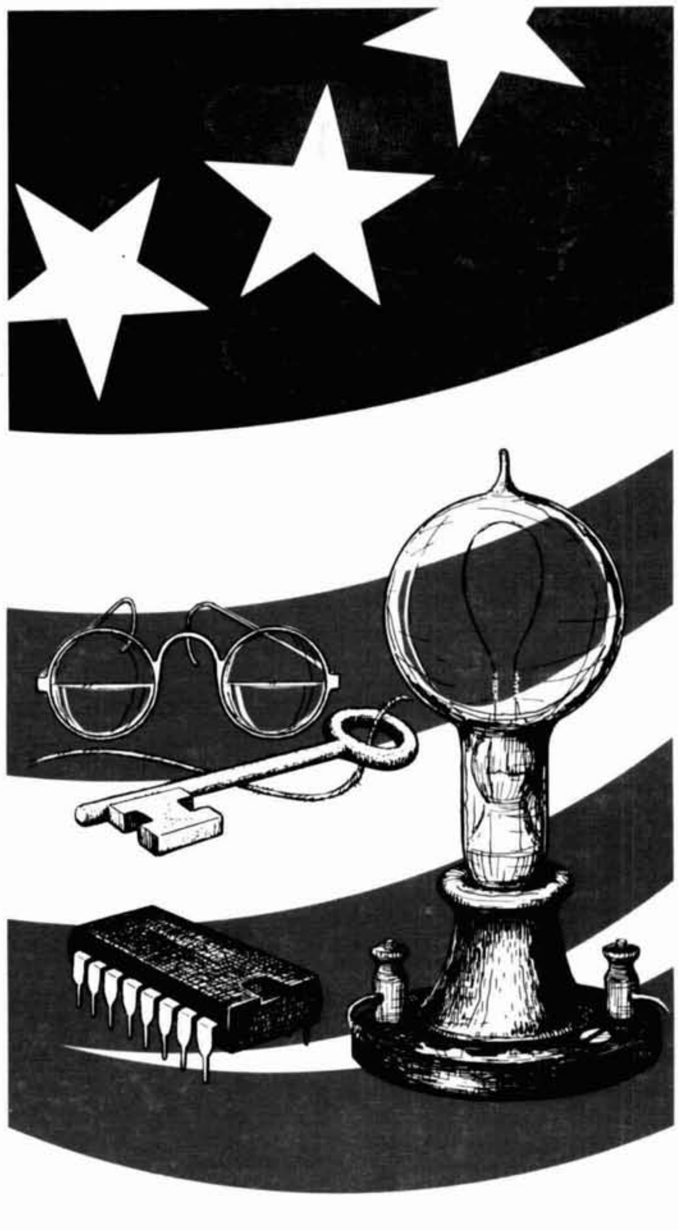
ham radio

magazine

JULY 1976



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The HAL ST-6000 demodulator /keyer and the DS-3000 and DS-4000 KSR/RO series of communications terminals are designed to give you superlative TTY performance today —and in the future. DS series terminals, for example, are re-programmable, assuring you freedom from obsolescence. Sophisticated systems all, these HAL products are attractively priced—for industry, government and serious amateur radio operators.

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These are some of the highlights. The full range of features and specifications for the ST-6000 and the DS series of KSR and RO terminals is covered in comprehensive data sheets available on request. Write for them now—and tune in to the most sophisticated TTY operation you can have today... or in the future.

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contents

a second look

by Jim Fisk

Although many of the great discoveries in the natural sciences occured in the 18th century, when the Declaration of Independence was signed in Philadelphia 200 years ago, little was known about electricity – most of the great scientific minds of the day were focusing their attention in other areas. However, one of the signers of the document that proclaimed the independence of men as individuals, Ben Franklin, had flown his famous kite some twenty years earlier, thus proving the connection between lightning and electricity.

When Franklin first became interested in electricity in 1746, science – or natural philosophy, as it was then called – was practically nonexistent in America. Americans were forbidden by the British to engage in arts and crafts based on natural phenomena, the Puritan ethic persisted, and men were still cautious about new notions that ran counter to popular belief. Until Franklin's time all that was known about electricity was that when certain substances – such as sulfur or glass – were rubbed, they attracted other light substances, such as bits of paper. No one knew why. Sparks could also be made to jump from the rubbed material to a finger tip, and experimenters noted that the accompanying smell and cracking noise were similar to that produced by lightning. In 1749 Franklin first suggested the "sameness of lightning with electricity," but it was two years later before his paper was published in Paris. The experiment was immediately carried out by two Frenchmen, carefully following Franklin's instructions, one month *before* Franklin's kite flying episode.

Although many others tried the same experiment, not all were as lucky as Franklin. George Richmann, a Swede working in Russia, failed to ground his apparatus – as Franklin had suggested – and paid the consequences: a foot-long spark jumped from the rod to Richmann's head and made him the first martyr to the new science.

Although it was the lightning rod that made Franklin a demigod to his contemporaries (the French thought he was the reincarnation of Socrates and slept with his portrait under their pillows), his contributions were much more profound: he unified the disorderly body of existing knowledge that provided a basis for all subsequent advances. Lacking terminology, Franklin invented words as he went along, providing a lexicon of electricity that is still used today. His condenser (or "battery" as he called it) formed an evolutionary link between the short-time sparks of the Leyden jar and the continuous current of the later voltaic cell. He established the positive-negative nature of electricity, hinted at the existance of a basic charge and his single-fluid theory led directly to the concept of electrons moving through conductors. In barely ten years, by trial and error, using simple tools, he had moved a primitive science into the modern world of the 18th century.

After Franklin, the focus of electrical discovery shifted back to Europe, where it would remain for nearly 100 years; Americans were much too involved in the progress of their fast developing country to spend much time or money in nebulous scientific pursuits. It wasn't until 1840, when Samuel B. Morse patented his telegraph, that attention again focused on America.

Morse, a successful portrait painter who knew next to nothing about the basic principles of electricity, had seen some experiments dealing with electromagnetism in Europe in the 1830s and wondered if the effect could be used to send messages over a wire. He made some sketches during his voyage back from Europe, and spent the next three years trying to build the device he had sketched, but nothing came of his work. Lack of knowledge didn't stop him. When Congress offered a $30,000 prize for a 1000-mile system, Morse plunged headlong into the search for a practical telegraph. When one of his colleagues, Leonard Gale, saw one of Morse's unsuccessful machines he pointed out the need for insulation on the windings of the electromagnets, and showed Morse how to arrange the battery circuit. A backer, Stephen Vail, agreed to put up $2000 if Morse would take on his son Alfred. Morse agreed, and it was Alfred Vail who worked out the final form of Morse's code, introduced the key, and reduced the equipment to its final, compact form. It was also Vail who invented the printing telegraph that was patented in Morse's name.

Before 1838, when the patent law was enacted by Congress, only about 500 patents had been granted, but within three years after the patent law more than 10,000 patents were issued. Soon to come were the telephone, the incandescent lamp, the electrical generator, the transatlantic cable and the wireless telegraph. Each of these would lead to thousands of by-products, to major new industries, and to the rapidly advancing electronic technology of the 20th century.

Jim Fisk, W1DTY
editor-in-chief

Now ICOM Introduces 15 Channels of FM to Go!

The New IC-215: the FM Grabber

This is ICOM's first FM portable, and it puts good times on the go. Change vehicles, walk through the park, climb a hill, and ICOM quality FM communications go right along with you. Long lasting internal batteries make portable FM really portable, while accessible features make conversion to external power and antenna fast and easy.

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- Fully collapsible antenna
- Compatible mount feature for flexible antenna
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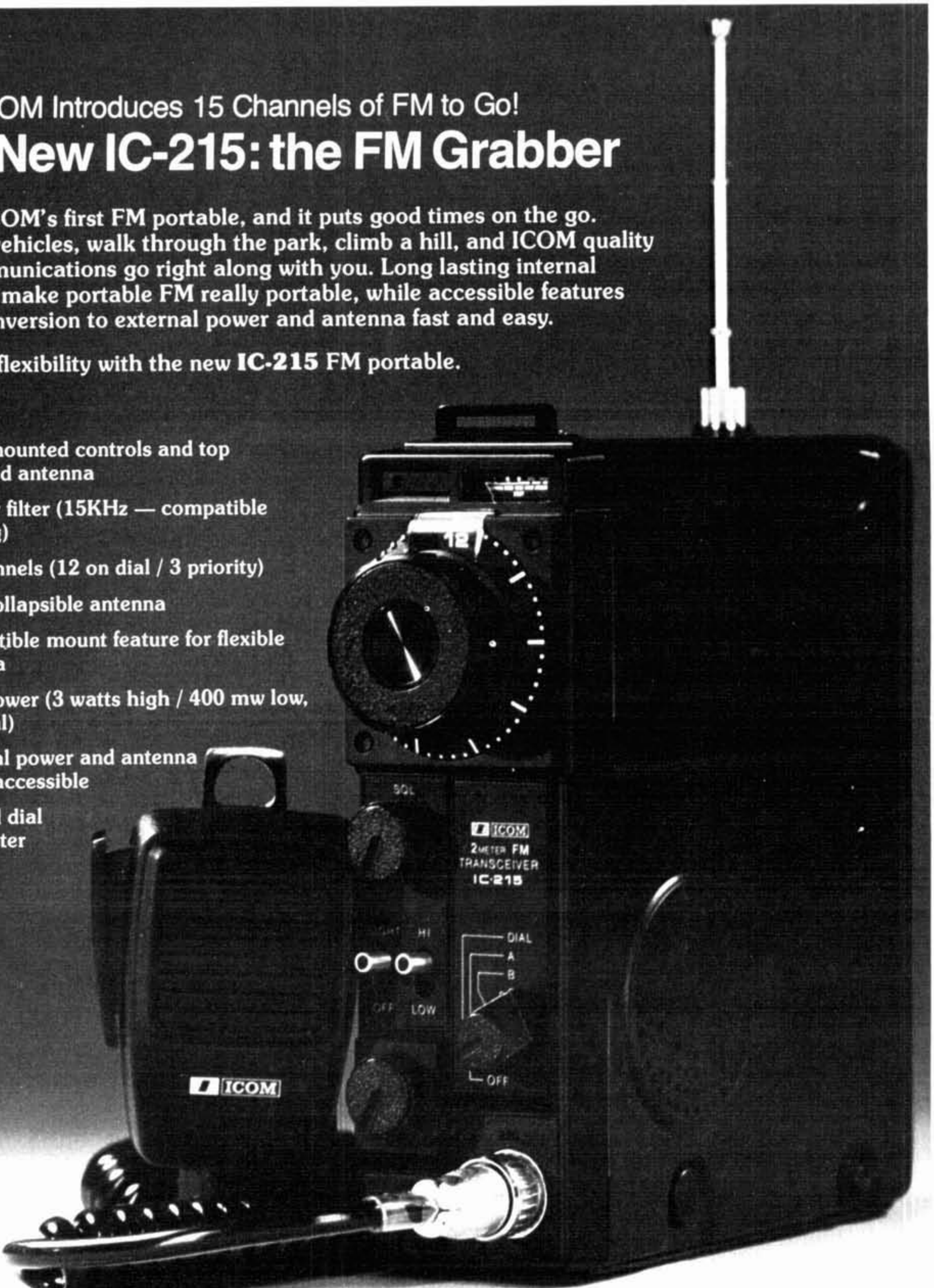
- External power and antenna easily accessible
- Lighted dial and meter



Your new **IC-215** comes supplied with: 5 popular channels; handheld mic, with protective case; shoulder strap; connectors for external power and speaker; 9 long-life C batteries.

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More Details? CHECK—OFF Page 118

presstop

MOST NEW AMATEUR HF receivers and transceivers would have to be certified that they meet FCC Part 15 radiation limits under a Notice of Proposed Rule Making recently released by the Commission. Docket 20746 would limit conducted radiation (at the antenna terminals) of receivers capable of tuning in the 26- to 30-MHz region to 100 microvolts from 450 kHz through 25 MHz, with additional radiation limits extending to 3 GHz.

Receiver Radiation Problem came to a head when one popular synthesized CB receiver was found to be radiating sufficient RF in the 37-MHz area that it was interfering with mobile communications in the Power Radio Service.

FCC'S BANDWIDTH DOCKET, 20777, steps on a number of toes and their owners are not at all happy about it. Fast-scan TVers were quickest and most vehement in their reaction to their suggested exile to above 1215 MHz, but the many AM users on 160 meters are also starting to become aware of their jeopardy.

Less Obvious Problems beginning to be discussed are potential conflicts between 850-Hz RTTY, facsimile, slow-scan TV and phone operators on all the present phone bands and the use of modulated CW in the CW segments.

FCC APPROVED ARRL'S TRAINING CONCEPT in mid May, to be tried as an experimental one-year program. The League has proposed a carefully monitored training course of 10 to 12 lessons to be conducted by qualified, certified instructors. Upon satisfactory completion of the course the student would be certified "qualified for Novice license" to the FCC, which would then issue him a license without further exam. By the time you read this approximately 40 clubs and organizations will be teaching courses under this program on a trial basis.

Three Key Stipulations in the FCC's decision favoring the ARRL proposal are an insistence that the integrity of any examinations used in the course be absolute, the instructors must be adequately qualified, and administration of the program must not be restricted to a single organization. Though the FCC is apparently willing to delegate responsibility for determining instructor qualifications to the League, it does not (and probably legally cannot) give the ARRL an exclusive claim on what will surely become a lucrative marketplace.

CHARLOTTE REID RESIGNED from the FCC and will be leaving the Commission on June 30. In the letter of resignation she submitted to President Ford, Commissioner Reid stated that she had just married H. Ashley Barber of Aurora, Illinois and would be returning to Illinois to live later this summer.

Commissioner Reid was also very active in matters affecting Amateur Radio and showed herself to be a real friend of the Amateur service on numerous occasions. She was also an honorary member of AFAR, the Aurora (Illinois) repeater group. Her presence on the Commission will be missed by the Amateur Community.

220-MHZ CLASS-E CB was dealt another blow by a submission filed with the Commission May 3 by the Association of Maximum Service Telecasters, a TV broadcasters' group. Heart of the submission was an April 20 report from A.D. Ring & Associates, a Washington consulting radio engineering firm, stating that severe interference could occur to channel 13 TV reception in an urban area from a 25-watt, 220-MHz mobile at a distance up to 300 feet, while areas where channels 11 and 13 are both in use could experience similar problems out to 1000 feet.

AMATEUR AND CB RADIO RULES have finally been split into separate volumes by the Government Printing Office. First out is the CB volume — Part 95 — which is now available from the GPO or one of its stores in major cities for $1.50 (stock number 004-000-00324-1). Part 97, Rules for the Amateur Radio Service, will become available this summer and also costs $1.50 (stock number 004-000-00325-0). Part 99 for the disaster Communications Service, stock number 004-000-00326-8, is due out momentarily and will cost 75¢. Any or all can be ordered now from the Superintendent of Documents, GPO, Washington D.C. 20402 or the Public Documents Distribution Center, Pueblo, Colorado 81009.

NASA HAS APPROVED AMSAT'S request to "piggy back" OSCAR 8 into orbit on a launch sometime in 1977 or 1978. At this time mid 1977 looks likely, leaving the various contributors to the new Amateur satellite precious little preparation time.

OSCAR 8 Frequencies were proposed at the command station operator's meeting. Tentative choices are: 435.15-435.29 in and 145.850-145.990 out for one mode; 145.850-145.990 in, 435.150-435.290 out for the alternate mode. Beacon frequencies proposed are 435.300, 435.145, 145.995 and 145.845. User comments on all these choices are solicited.

SOUTH AMERICA'S FIRST 432 MOONBOUNCE will be available this summer thanks to Mount Airy VHF Club (the Pack Rats) and the Colombian government. Three Pack Rats, W3HQT, K3BPP and W3HMU, will accompany a complete EME station to Barranquilla, Colombia in time for early August operation. They plan to be active for about two weeks on 432.040 MHz using high power and a portable 16 Yagi array.

Stateside Liaison will be handled through W3KKN and W3NTP at Callbook address or 215 659-3485; HK1BYM will handle the Colombian end. The group plans to field test the complete setup in the June 15-16 VHF QSO party from a portable location.

More Details? CHECK—OFF Page 118

either way is the right way

...they're both KENWOOD

the TR-7200A

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Complete with dynamic mike, DC power cord, mobile mount, mike hanger, auxiliary connector and external speaker plug. Amateur net . . . $249.00.

The perfect companion to the TR-7200A is the PS-5 AC/DC power supply. Together they provide an efficient and handsome base station. The PS-5 is complete with a digital clock and automatic time control feature built in. Amateur net . . . $79.00.

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Complete with Dynamic mike, O-T-S carrying case, all cables, speaker/headphone plug and 10 Ni-Cad batteries. Amateur net . . . $229.00.

TRIO-KENWOOD COMMUNICATIONS INC.

modern design of frequency synthesizers

A design review of today's synthesizers including a practical circuit for 41-71 MHz that provides low-noise output in 1-kHz steps

All frequency synthesizers use one of two methods to generate output frequencies for use in communications equipment: direct frequency synthesis and synthesis using the phase-lock technique. Direct frequency synthesis has been extensively used in the past and has more or less been responsible for the word "synthesizer," which describes generators that provide accurate and stable frequencies derived from one frequency standard.

This article presents a survey of existing synthesizer technology. The major circuit elements comprising the frequency synthesizer are analyzed, with emphasis on recent design techniques of the phase-locked-loop method to achieve fast switching, low-noise, relatively spurious-free output at high frequencies. Special emphasis has been placed on the analysis of frequency dividers using TTL or cmos logic devices as synchronous counters, as well as phase discriminators using cmos logic. A practical synthesizer circuit for use in the 41 to 71 MHz range is also included, which employs most of the techniques described in the circuit analyses.

direct frequency synthesis

A typical arrangement of this method is shown in **fig. 1**, in which the desired output frequencies are created by mixing various individual frequencies. The output frequencies are not derived from one oscillator only but are obtained by mixing various frequency components, which are filtered out of a spectrum of frequencies.

Spectral purity. Spectral purity is a basic characteristic that defines synthesizer quality. It's important to distinguish between wide-band performance (that is, performance with sideband noise, which appears symmetrically about the carrier as modulation) and performance with spurious frequencies.

The selective filters used in the direct method determine the spurious-frequency response, and the sideband noise depends on the wideband-mixer power level and crystal-oscillator performance. The signal-to-noise performance of a direct synthesizer, up to 10 kHz off the carrier, is better than that of a free-running LC oscillator. Further off this carrier frequency, LC oscillators are better by definition because these oscillators can't produce wideband noise. Using direct synthesizers, 80 to 100 dB freedom from spurious response is obtainable, and the sideband noise is typically 130 dB/Hz at frequencies more than 20 kHz off the carrier.[1,2]

Switching Speed. Frequency change in direct synthesizers is achieved by switching filters. Switching times with only a few microseconds delay are obtainable; however, phase-coherent switching is not possible.

Disadvantages. The basic disadvantage of a system of this nature is the huge number of components and the requirement of expensive bandpass filters. It is hardly possible to build direct synthesizers above 1 GHz, because the intermediate frequencies will be so much higher that filters having the required performance are not feasible.

frequency analysis

Frequency analysis using phase-locked-loop techniques is a comparatively inexpensive method of obtaining multichannel frequency generators with high stability. For this method the following is important:

The output voltage is determined only from the voltage-controlled oscillator (one), and the exact frequency of this oscillator is determined by the loop. The low-pass filters used in this technique limit the bandwidth of the system where unwanted transients may cause frequency

By **Ulrich L. Rohde,** DJ2LR, 52 Hillcrest Drive, Upper Saddle River, New Jersey 07458

shift. To compare and synchronize the voltage controlled oscillator, which is at a different frequency than that of the reference-frequency oscillator, a mixing and dividing scheme is used for frequencies above 500 MHz, while phase-locked loops using only synchronous counters as dividers are used up to this frequency. This cutoff frequency is determined by the availablity of an integrated-circuit divider. **Fig 2** is a block diagram of such a synthesizer.

Spectral purity. An ideal phase-locked loop, which does not produce its own noise and spurious frequencies, will synchronize and transfer the performance of the crystal oscillator used as a reference to the voltage-controlled oscillator (vco). If the crystal oscillator noise performance is sufficient, the signal-to-noise performance of the vco can be improved, while a noisy reference can degrade the performance of the vco (i.e., an LC or voltage-controlled crystal oscillator). A typical application where the sideband noise and spurious frequencies of an oscillator can be reduced is in the synchronization of microwave oscillators (klystons, microwave tubes, microwave transistor oscillators). A phase-locked loop or synchronizing circuit can improve the performance dramatically. However, there is a limit to the possible improvement because the mixer and phase discriminator will produce noise or spikes.

In addition, the phase-locked-loop circuit acts as an integrating device, and good compensation is possible only when the loop gain is high enough. Because of the lowpass perfomance, close to the cutoff frequency, no noise or spurious frequency improvement can be achieved. **Fig. 3** shows the sideband noise performance of an LC oscillator, a vco synchronized with low loop bandwidth, a vco synchronized with wide loop bandwidth, a standard-quality crystal oscillator, and a high-performance crystal oscillator.

With respect to spurious frequencies, the phase-locked-loop circuit in its pure form (no frequency conversion involved) performs better than direct synthesis because the oscillator does not create any spurious frequencies. Complete freedom from spurious frequencies is impossible, because the loop reference frequency cannot be suppressed to values significantly better than 100 dB.

It is important to understand the following fact: If a frequency is divided, its value is reduced by the factor of the division. At the same time, the amplitude of the fm

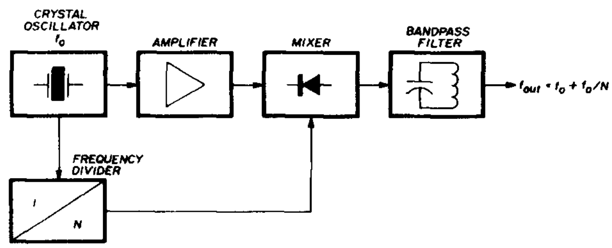


fig. 1. Direct synthesis method in which the output frequency, f_{out}, is equal to the crystal frequency, $f_o + f_o/n$ (division ratio), where n may be changed by using a switch.

spurious frequencies is reduced by the same amount; however, the value of the discrete frequency of the fm spectral line remains the same. For example, two discrete spurious sidebands are located ±100 kHz with respect to a 100-MHz carrier, and the carrier-frequency is divided by 100. The two sidebands are reduced by, say, 40 dB. The modulation index will be reduced by the division ratio, but the modulation frequency will remain constant.

The consequence of this action is that, in the case of a phase-locked-looped system with wide bandwidth, the sideband noise of the reference oscillator will be multiplied up; therefore, the crystal oscillator must be carefully designed in terms of noise performance. This disadvantage can be reduced by using filters of very narrow bandwidth. By doing so, it is possible to build an absolutely spurious-free generator that has the sideband noise response of the LC oscillator (vco). In a circuit such as

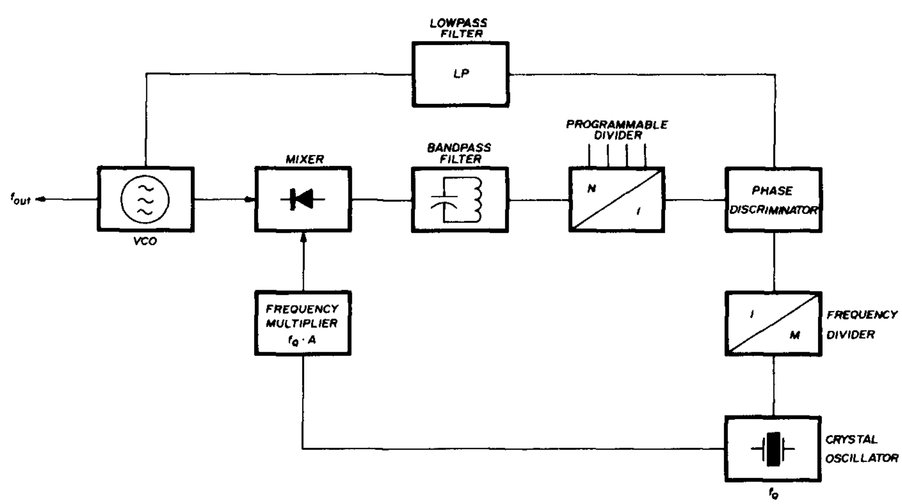


fig. 2. Phase-locked-loop arrangement with a reference frequency oscilllator, fQ. The vco frequency is mixed down, using A's harmonics of fQ as an auxiliary frequency to decrease the frequency to a value where integrated circuits are usable. If f_{out} equals 2 GHz and fQ equals 10 MHz, then A might be 180. The bandpass frequency would then be 200 MHz.

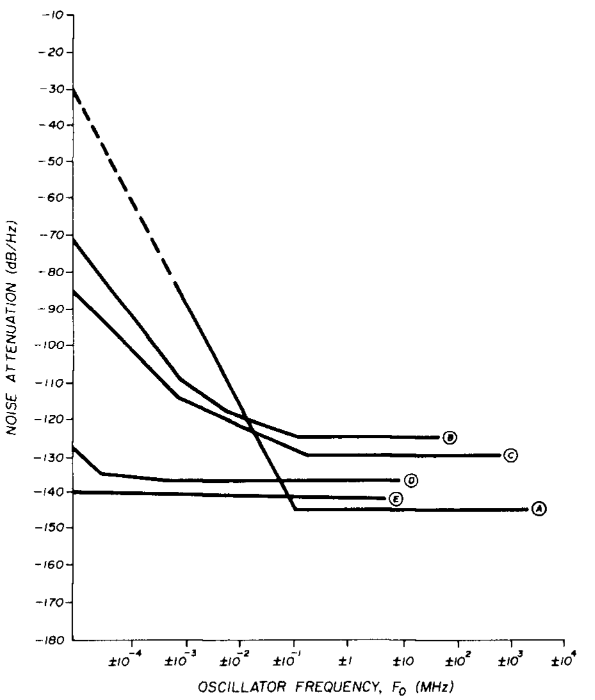


fig. 3. Noise sideband performance or various oscillators. Curve A represents a high-Q LC oscillator; B and C a vco synchronized with narrow and wide loop bandwidth, respectively. D shows the performance of a standard-quality crystal oscillator; E represents a high-performance crystal oscillator.

this, no noise improvement through the phase-locked-loop circuit will be achieved. It is also important to understand that, where extremely low-noise sidebands are required, loop bandwidths between 100 kHz and several MHz must be chosen.

Switching speed. The switching speed is determined by the loop cutoff frequency, depending upon the type of circuit used. In general, switching speed is almost 100 times slower than that of direct synthesizers. An advantage is that phase-coherent frequency switching is possible, which enables digital sweeping. This type of switching is much more accurate and is easily remote-controllable.

Advantages. Phase-locked loop synthesizers have the great advantage that very little filtering is required. In addition, most of the stages can be integrated and very little alignment is required.[3,4] Including harmonic synchronization (sampling techniques), synthesizers up to 10 GHz can be built.

voltage-controlled oscillators

To build low-noise voltage-controlled oscillators, a few design techniques must be considered. Up to 500 MHz, field-effect transistor oscillators show very little noise due to the reduced load they present to the LC circuit. They are superior to bipolar transistors. Since agc is required in some cases, and agc introduces some noise into the system, the performance of some bipolar transistor circuits nearly equals the performance of fets.

In some instances it is desirable to preset the vco to certain frequency bands; eg., 1 MHz wide. This is referred to as "coarse tuning" and is accomplished by using a digital-to-analog converter with sufficient filtering to avoid noise. This technique has the advantage that sample-hold discriminators, which are explained later, can be handled somewhat more easily.

Above 500 MHz only bipolar transistors or gallium-arsenide fets can be used. **Fig. 4** shows a typical field effect transistor vco, and **fig. 5** shows a typical bipolar vco. In some rare cases, voltage-controlled crystal oscillators are used; however, time constants of a few seconds will result, and circuits of this nature are used only where the lock time is of no concern. **Fig. 6** shows such an oscillator.

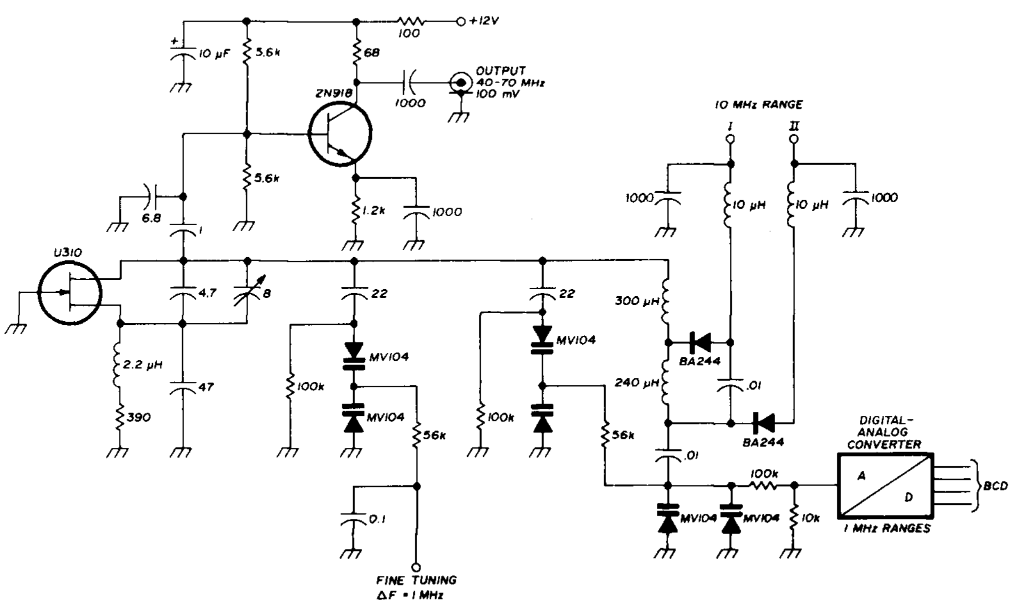


fig. 4. Field-effect transistor vco with coarse and fine tuning, using a digital-to-analog (D/A) converter for presetting.

frequency dividers

TTL or cmos integrated circuits can be used as synchronous counters. Typical ICs are 74192 (TTL), 74C192 and CD4018 (cmos). To extend the frequency range to 500 MHz, so-called "swallow counters" are being used. The most popular swallow counters are the 95H90 made by Fairchild* and the Plessey SP8640. The division ratio of a swallow counter is controlled by two inputs. The counter will divide by 10 when either input is in the high state and by 11 when both inputs are in the low state.

This 10/11 division ratio enables you to build fully programmable dividers to 500 MHz. The switch counting principle means that high-frequency prescaling occurs without any reduction in comparison frequency. The disadvantage of this technique is that a fully programmable divider is required to control the 10/11 division ratio and that a minimum limit is set on the decision ratio possible — although this is not a serious problem in a practical loop. **Fig. 7** uses a division ratio of *P/P+1*, which is set to 10/11. The A counter counts the units, and the B counter counts the 10s.

Consider the system shown in **fig. 7**. If the *P/P+1* is a 10/11 divider, the **A** counter counts the units and the **M** counter counts the tens. The mode of operation depends on the type of programmable counter used, but the system might operate as follows. If the number loaded into **A** is greater than zero, then the *P/P+1* divider is set to divide by *P+1* at the start of the cycle. The output from the *P/P+1* divider clocks both **A** and **M**. When **A** is full, it ceases counting and sets the *P/P+1* divider into the *P* mode. Only **M** is then clocked, and when it is full, it resets both **A** and **M** and the cycle repeats.

The divider chain therefore divides by:

$$(M-A)\,P+A\,(P+1) = MP + A \qquad \mathbf{(1)}$$

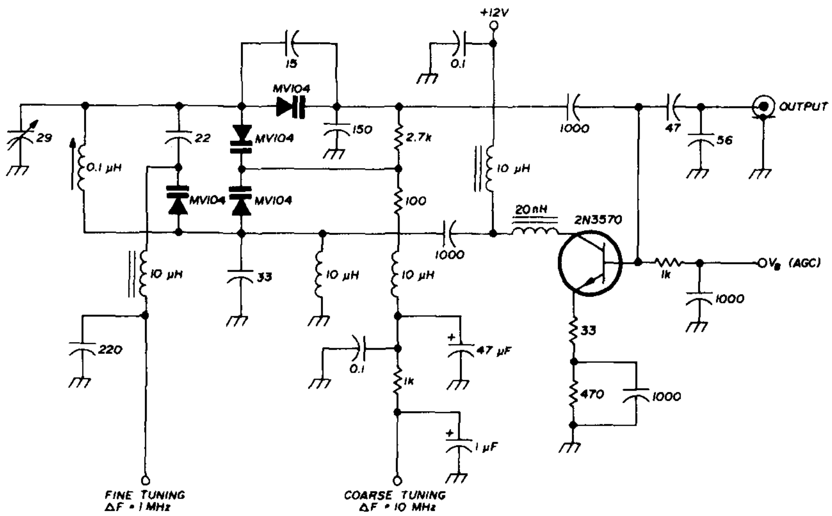


fig. 5. Bipolar vco with fine and coarse tuning.

*The Fairchild 95H90, which is recommended for operation up to 350 MHz, has recently been superseded by the 11C90 which has a top frequency rating of 520 MHz at room temperature.

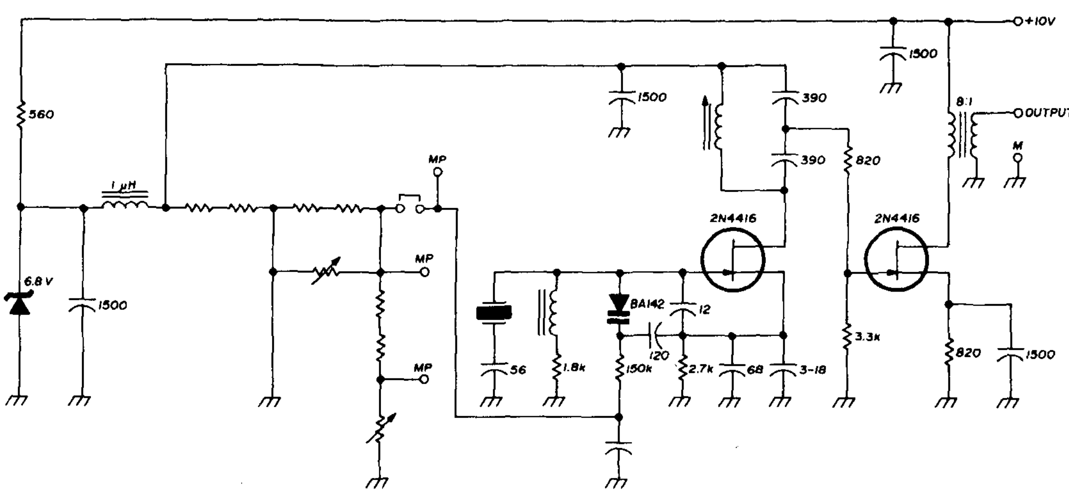


fig. 6. Vcxo circuit with a temperature-compensating network. Instead of using this circuit, a dc voltage may be applied to shift the frequency to desired values. Third- or fifth-overtone crystal oscillators are required for extremely low sideband noise.

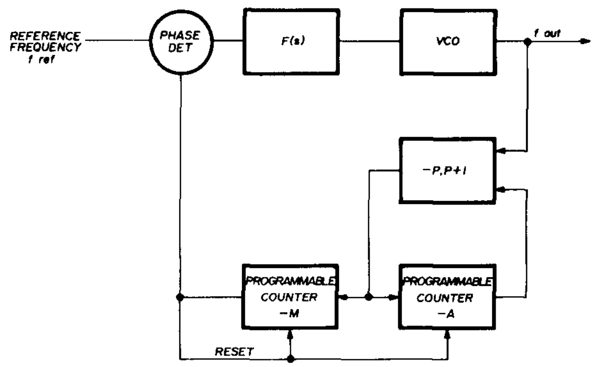


fig. 7. Simplified block diagram of a synthesizer using a programmable prescaler.

therefore

$$f_{out} = (MP + A)\, f_{ref} \qquad (2)$$

If A is incremented by one, the output frequency changes by f_{ref}. In other words, the channel spacing is equal to f_{ref}. This is the channel spacing that would be obtained with a fully programmable divider operating at the same frequency as the *P/P+1* divider.

For this system to work, the A counter must fill before the M counter does, otherwise *P/P+1* will remain permanently in the *P+1* mode. There is therefore a minimum system division ratio, M_{min}, below which the *P/P+1* system will not function. To find that minimum ratio, consider the following

The A counter must be capable of counting all numbers up to and including $P-1$ if every division ratio is to be possible, or:

$$A_{max} = P - 1 \qquad (3)$$

$$M_{min} = P, \text{ since } M > A \qquad (4)$$

The divider chain divides by *MP+A*, therefore the minimum system division ratio is:

$$M_{min} = M_{min}\,(P + A_{min})$$
$$= P\,(P + 0) = p^2 \qquad (5)$$

Using a 10/11 ratio, the minimum practical division ratio of this system is 100.

In the system shown in **fig. 7**, the fully programmable counter, A, must be quite fast. With a 350-MHz clock to the 10/11 divider, only about 23 ns are available for counter A to control the 10/11 divider. For cost reasons

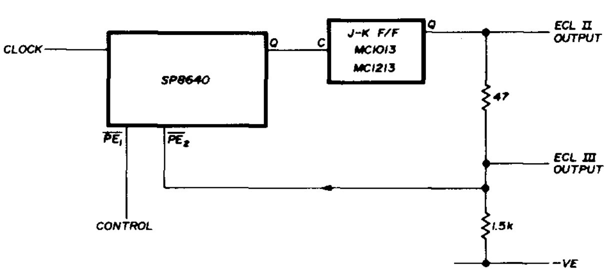


fig. 8. Prescaler with a 20/21 division ratio.

it would be desirable to use a TTL fully-programmable counter, but when the delays through the ECL-to-TTL translators have been taken into account, very little time remains for the fully-programmable counter. The 10/11 function can be extended easily, however, to give a *÷N/N+1* counter with a longer control time for a given input frequency, as shown in **figs. 8** and **9**. Using the 20/21 system shown in **fig. 8**, the time available to control 20/21 is typically 87 ns at 200 MHz and 44 ns at 350 MHz. The time available to control the 40/41 (**fig. 9**) is approximately 180 ns at 200 MHz and 95 ns at 350 MHz.

This frequency division technique can, of course, be extended to give 80/81, which would allow the control to be implemented with cmos, but which would increase the minimum division ratio to 6400 (80^2). This ratio is too large for many synthesizer applications, but it can be reduced to 3200 by making the counter a 80/81/81. Similarly, a 40/41 can be extended to 40/41/42, as

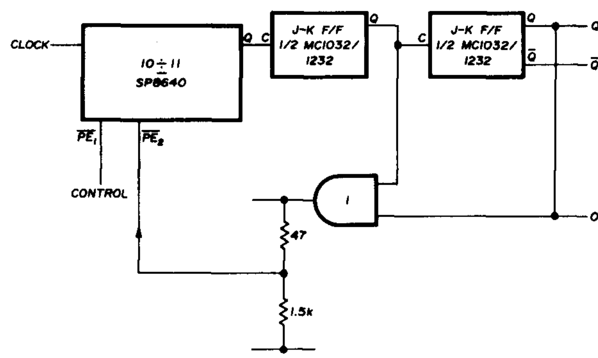


fig. 9. Prescaler system with a 40/41 division ratio.

shown in **fig. 10**, to reduce the minimum division ratio from 1600 to 800. The time available to control the 40/41/42 is a full 40 clock pulses; i.e., 200 ns with a 200-MHz input clock or 110 ns at 350 MHz. The principle of operation is:

Minimum division ratio

$800 = (20 \times 40) + (0 \times 41) + (0 \times 42)$

$801 = (19 \times 40) + (1 \times 41)$

$802 = (19 \times 40) + (2 \times 42)$

More information can be found in reference 5.

In most cases the oscillator must drive an ECL divider. **Fig. 11** shows a simple method using two transistors in a differential amplifier to achieve the nonsaturated voltage swing.

In dealing with counters it must be remembered that, because of the switching action, the counter input represents a high and a low impedance as a function of the status. This means loading the oscillator output stage. Especially when using swallow counters, or so-called variable-modulus counters where unsymmetrical loading occurs, the input signal will show phase modulation. This phase modulation will appear at the counter chain output as excessive sideband noise much larger in magnitude than that contributed by the vco.

To avoid this problem, a low-impedance stage should be used between the buffer amplifier and the prescaler input; A suitable buffer amplifier is the SN72733, made by Texas Instruments, which has a cutoff frequency of 200 MHz. A common-emitter stage with a 50-ohm load resistor following is a suitable decoupling scheme. **Fig 12** shows such an arrangement. Slightly better noise performance is obtained by using the Plessey SP8690 prescaler. This device has a substantially higher input impedance and needs less surrounding circuitry.

lowpass filter is required. Suitable formulas for designing these filters can be found in reference 6. To the best of my knowledge, that book is the best collection of filter tables on the market.

phase discriminators

Various forms of phase discriminators are available. The simplest uses a double-balanced mixer in which two identical frequencies applied to the rf port and local-oscillator port result in a dc output voltage, which must be filtered. Flip-flop discriminators have recently become very popular. The Motorola phase-locked-loop handbook refers to this type of discriminator only because of the ease of its design.[7] However, conventional flip-flop discriminators have significant disadvantages because of the permanent ripple at the output. Therefore, the loop filter cutoff frequency has a tendency of being only 1% or less of the reference frequency so this technique, in practice, does not take advantage of the

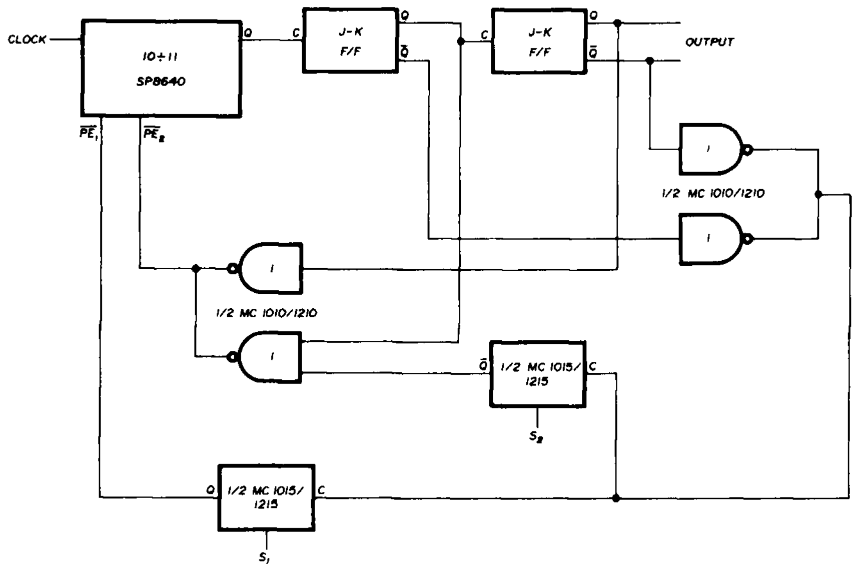


fig. 10. A 40/41 prescaler extended to a 40/41/42 system to reduce the minimum division ratio.

In cases where the synthesizer must be modulated, mixing schemes are used, and the frequency that represents the auxiliary frequency is modulated. Careful selection of the proper mixer and filtering techniques is required to avoid spurious frequencies in the synthesizer. In addition, well-shielded cabinets are required to avoid radiation problems. **Fig 13** shows a typical mixing arrangement with adequate filtering. The harmonics of the oscillator frequency to be converted down may produce spurious frequencies, which means that an expensive

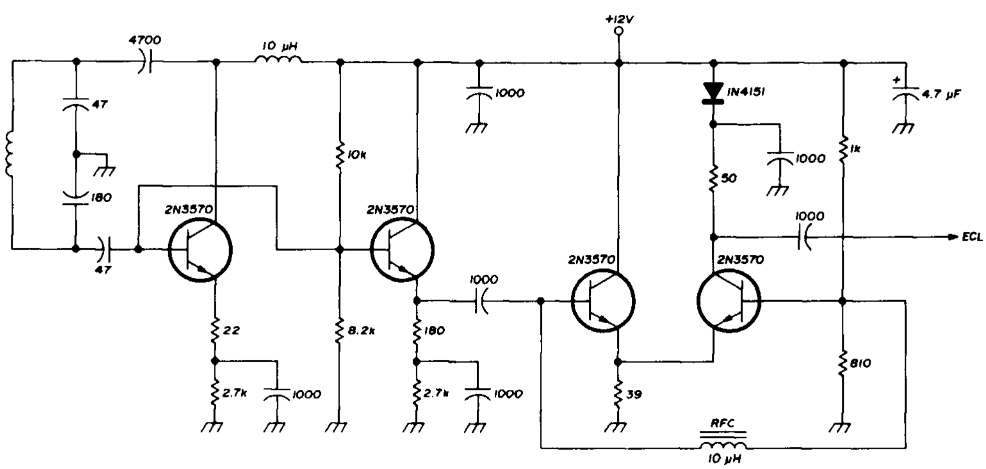


fig. 11. Oscillator circuit with a buffer stage and an ECL voltage translator, using two transistors as a differential amplifier.

possibilities of improving vco noise performance.

Because of the additional introduction of a bipolar transistor as a current charge pump, the sideband noise performance is almost degraded, so the flip-flop technique is seldom used in high-performance synthesizers. Complete information on flip-flop discriminators is given in the Motorola handbook previously mentioned.[7]

The introduction of the RCA CD4046A integrated circuit containing a new type of phase comparator represents a big step forward. **Fig. 14** shows a schematic of this cos/mos phase comparator, which is an edge-controlled digital memory network. It consists of four flip-flop stages, control gating, and a three-stage output circuit comprising p- and n-type field-effect transistors. When the p-mos and n-mos drivers are on, they pull the output up to V_{DD} or down to V_{SS}, respectively. This type of phase comparator acts only on the positive edges of the signal and comparator-input signals.

The duty cycles of the signal and comparator inputs are not important, since positive transitions control the PLL system. If the signal-input frequency is higher than that of the comparator input, the p-mos output driver will be *on* continuously. If the signal-input frequency is lower than that of the comparator input, the n-mos output driver will be *on* continuously. If the signal and comparator-input frequencies are the same, but the signal input lags the comparator input in phase, the n-mos output driver will be *on* for a time corresponding to the phase difference.

If the signal- and comparator-input frequencies are the same, but the signal input leads the comparator input in phase, the p-mos output driver will be *on* for the time corresponding to the phase difference. The capacitor voltage of the lowpass filter connected to this type of phase comparator must be adjusted until the signal and comparator input are equal in both phase and frequency At this stable operating point, both p- and n-mos output drivers will remain *off*, and thus the phase-comparator output will become an open circuit and will hold the voltage constant on the capacitor of the lowpass filter.

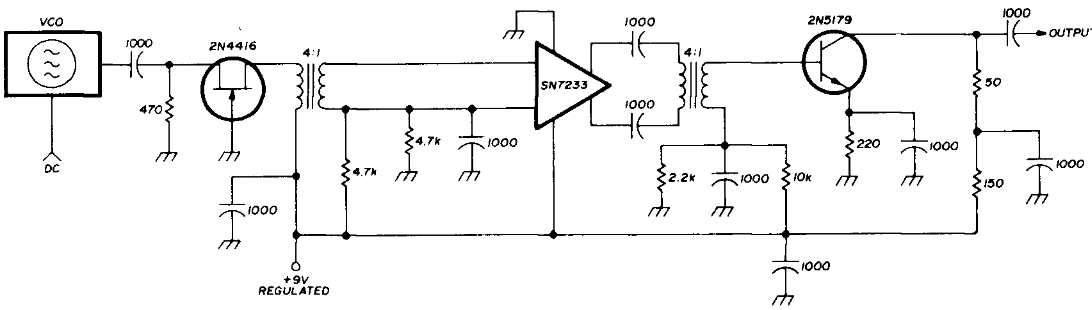


fig. 12. Suitable decoupler arrangement with high gain and low impedance to drive medium-impedance prescalers.

Moreover, the signal at the "phase pulses" output will be at a high level and can be used for indicating a locked condition. Thus, for phase comparator II, no phase difference will exist between signal and comparator input over the full vco frequency range. In addition, the power dissipation due to the lowpass filter will be reduced when this type of phase comparator is used, because both the p- and n-mos output drivers will be *off* for most of the signal-input cycle. It should be noted that the PLL lock range for this type of phase comparator will be equal to the capture range, independent of the lowpass filter. With no signal present at the signal input, the vco is adjusted to its lowest frequency for phase comparator II. **Fig. 15** shows typical waveforms for a cos/mos phase-locked loop employing phase comparator II in a locked condition.

Fig. 16 shows the state diagram for phase comparator II; each circle represents a state of the comparator. The number at the top of each circle represents the state of

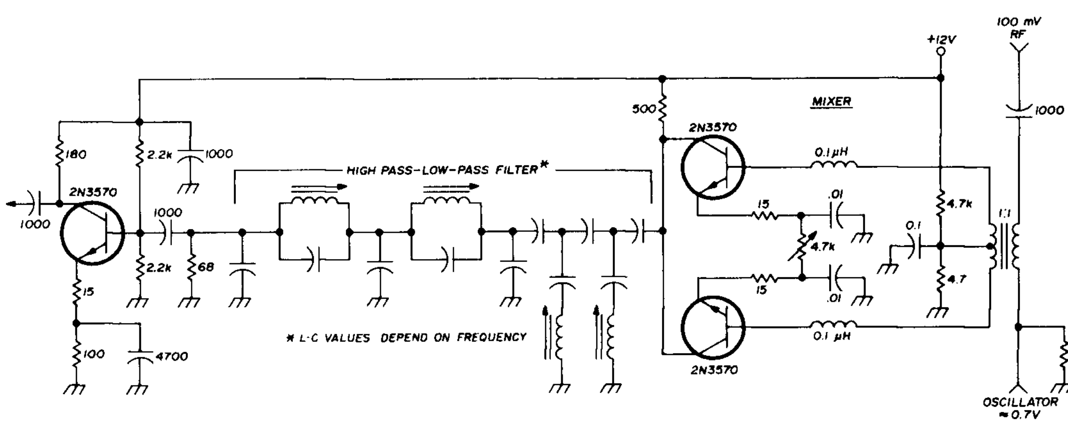


fig. 13. Active mixer for synthesizers requiring 700 mV drive level, together with a highpass-lowpass filter and proper termination.

the comparator, while the logic state of signal and comparator inputs, represented by a 0 or a 1, are given by the left- and right-hand numbers, respectively, at the bottom of each circle.

The transitions from one state to another result from either a logic change on the signal input (I) or the comparator input (C). A positive transition and a negative transition are shown by an arrow pointing up or down, respectively. In the state diagram, it is assumed that only one transition on either the signal input or the comparator input occurs at any instant. States 3, 5, 9, and 11 represent the condition at the output of phase comparator II when the p-mos driver is *on*, while states 2, 4, 10, and 12 determine the condition when the n-mos driver is *on*. States 1, 6, 7, and 8 represent the condition when the output of phase comparator II is in its high-impedance state; i.e., both p- and n- devices are *off*, and the phase-pulses output (terminal 1) is high. The condition at the phase-pulses output for all other states is low.

As an example of how you can use the state diagram shown in **fig. 16**, consider the operation of phase comparator II in the locked condition as shown in **fig. 15.** The waveforms in **fig. 15** are shown in three parts. Part I corresponds to the condition in which the signal input leads the comparator input in phase, while part II corresponds to a finite phase difference. Part III depicts the condition when the comparator input leads the signal input in phase. These three parts correspond to a locked condition for the cos/mos phase-locked loop; i.e., both signal- and comparator-input signals are of the same frequency but differ slightly in phase.

Assume that both the signal inputs begin in the 0 state, and that phase comparator II is initially in its high-impedance output condition (state I), as shown in **figs. 16** and **15**, respectively. The signal input makes a positive transition first, which brings phase comparator II to state 3. State 3 corresponds to the condition of the comparator in which the signal input is a 1, the comparator input is a 0, and the output p-device is *on*. The comparator input goes high next while the signal input is high, bringing the comparator to state 6, a high-impedance output condition. The signal input goes to zero next while the comparator input is high, which corresponds to state 7. The comparator input then goes low, bringing phase comparator II back to state 1.

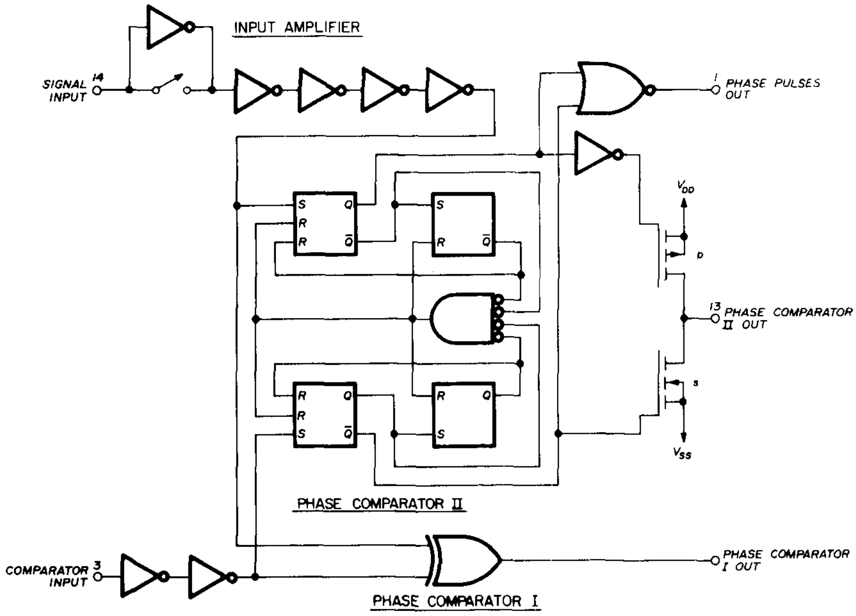
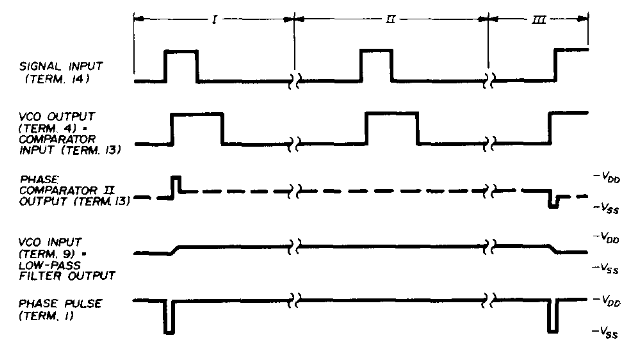


fig. 14. Phase comparator portions of the RCA CD4046A.

As shown for part I of **fig. 15**, the p-device stays on for a time corresponding to the phase difference between the signal input and the comparator input. Starting in state 1 at the beginning of part III, the comparator input goes high first while the signal input is low, bringing the comparator to state 2. Following the example given for part I, the comparator proceeds from state 2 to states 6 and 8, then back to 1. The output of phase comparator II for part II corresponds to the n-device being on for a time equal to the phase difference



NOTE: DASHED LINE IS AN OPEN-CIRCUIT CONDITION.

fig. 15. Typical waveforms for the cmos phase comparator in locked condition.

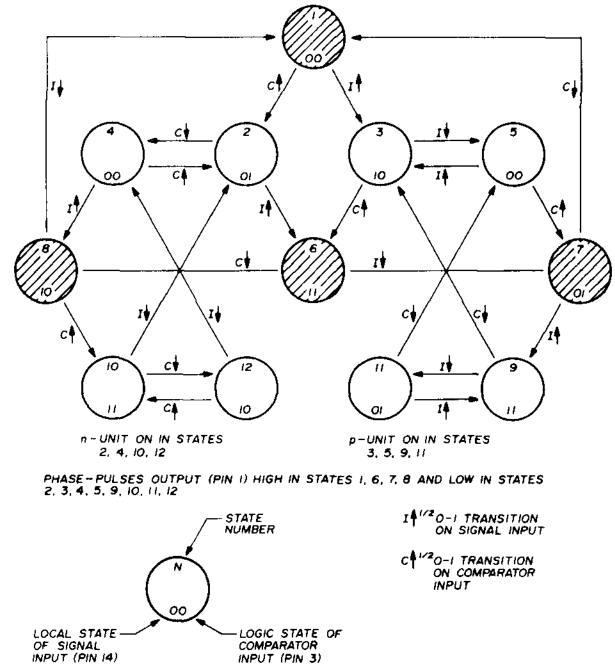
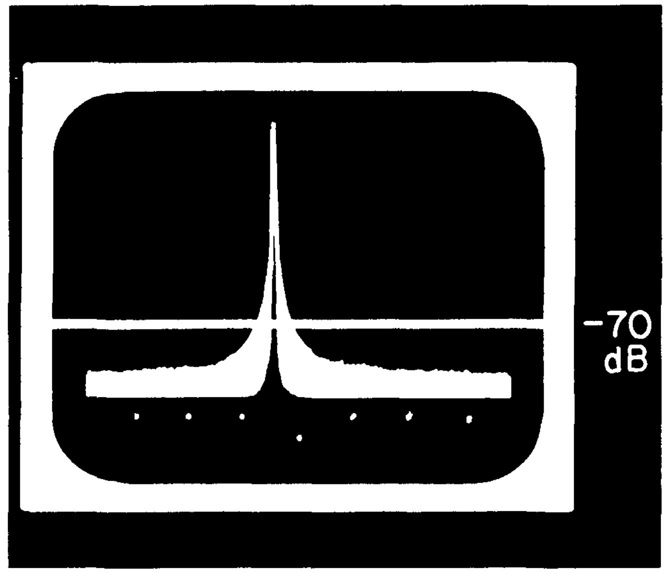


fig. 16. State diagram of phase comparator II in the CD4046 IC.

between the signal and comparator inputs. The state diagram of phase comparator II completely describes all modes of operation of the comparator for any input condition in a phase-locked loop.[8]

As can be seen from **fig. 15**, the phase comparator II output voltage is a dc voltage, a big advantage over the discriminators used by Motorola. The other important feature is that it uses low-current cmos devices. Building very clean synthesizers can become difficult and expensive because of the shielding involved. Radio-frequency noise created from switching, using TTL devices, will contain much more energy than that from mos devices. In addition, using cmos, the power supply is much simpler. Therefore, it is strongly recommended that cmos be used where possible to take advantage of the inherent good properties of the RCA CD4046 discriminator. This type of circuit comes very close to the sample-hold discriminator, which has been known for quite some time. The sample-hold discriminator requires somewhat more circuitry; however, it offers the best possible reference noise suppression.

The divider-chain output (square wave) is converted into a sawtooth voltage, which is sampled using a switch



Example of a 145-MHz carrier signal. The reference line is 70 dB down; frequency markers are spaced 10 kHz. Excessive noise starts about 60 dB down, which does not fall off completely.

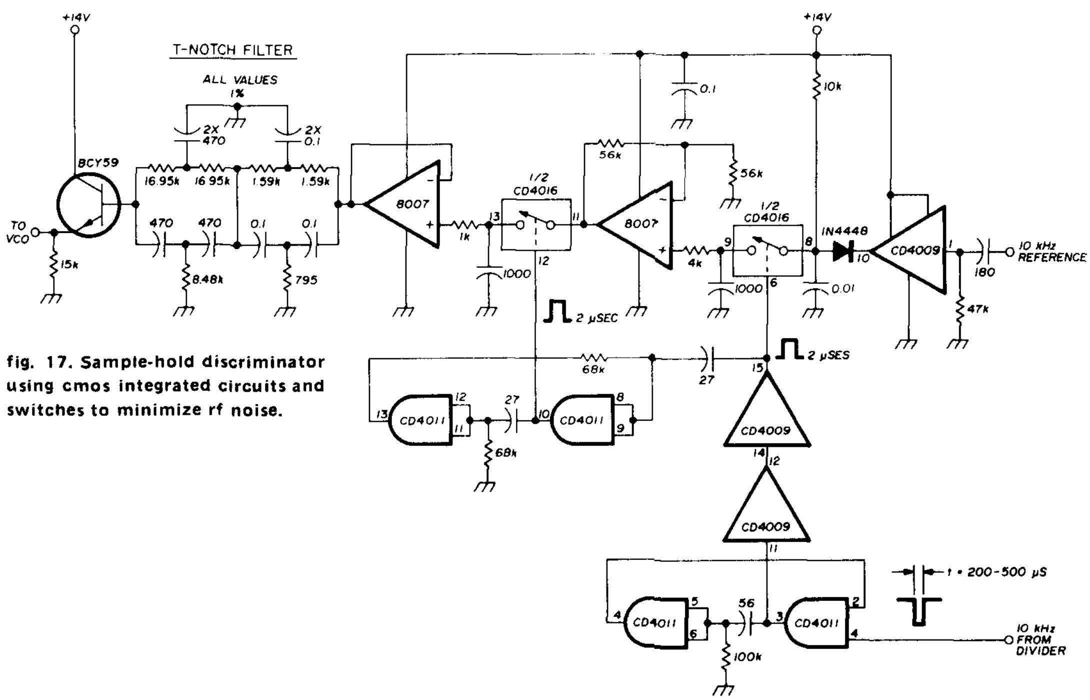


fig. 17. Sample-hold discriminator using cmos integrated circuits and switches to minimize rf noise.

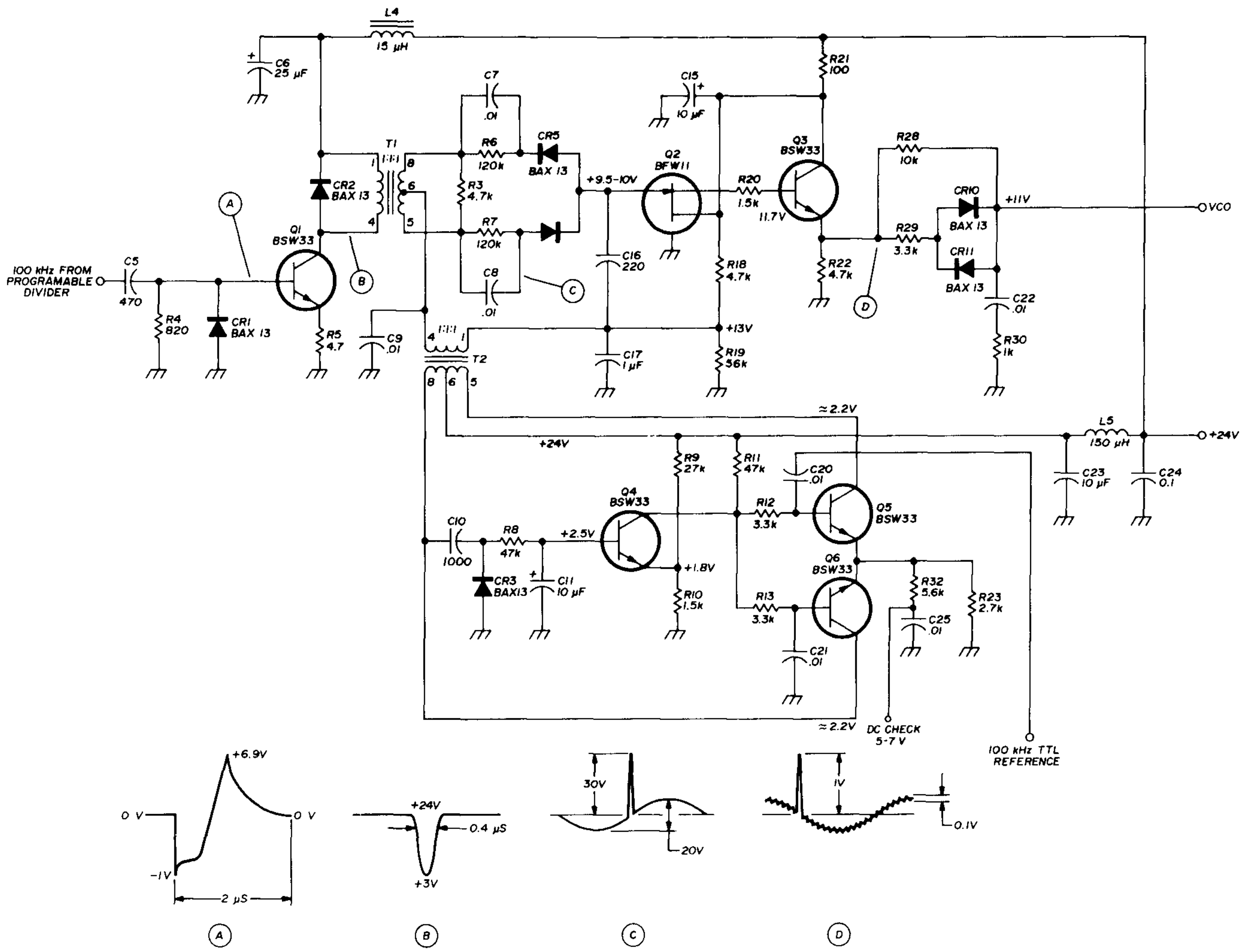


fig. 18. Balanced modulator circuit in a switching arrangement for superior sideband noise performance as a phase comparator.

(sample-hold discriminator). This output voltage is used to charge a capacitor, and the discriminator holds the charge as long as phase and frequency remain the same. If the phase changes, this switch will charge or discharge the capacitor, so that the dc control voltage will also change. Crosstalk or feedthrough is extremely small; the reference noise can be suppressed by 60 dB. However, the fast switching creates spikes, which will produce spurious output.

To reduce spurious output, two sample-hold discriminators are cascaded as in **fig. 17**, which shows a typical arrangement including the waveform-changing stages. The input from the reference divider, which in our arbitrary case is 10 kHz, is used to trigger gate CD4009, and the arrangement with the diode and the RC combination produces a sawtooth waveform (fast charge-slow discharge). The cmos CD4016 receives its input from the reference divider. This input frequency is exactly 10 kHz.

Since the input signal pulse may be a bit too narrow, a one-shot with two gates is used, and the signal now is 2 microseconds wide. The input of the first switch charges a 1000 pF capacitor, and the following Intersil 8007 mos operational amplifier is the low-impedance source for the second CD4016 switch. The input signal to this switch, which is derived from a second one-shot, is delayed; therefore unwanted spikes are suppressed.

The second 8007 operational amplifier drives a T-notch filter. One leg has a 10-kHz resonant frequency; the other 20 kHz. A notch depth of 60 dB can be achieved. The BCY59 transistor is an emitter follower, which drives the vco.

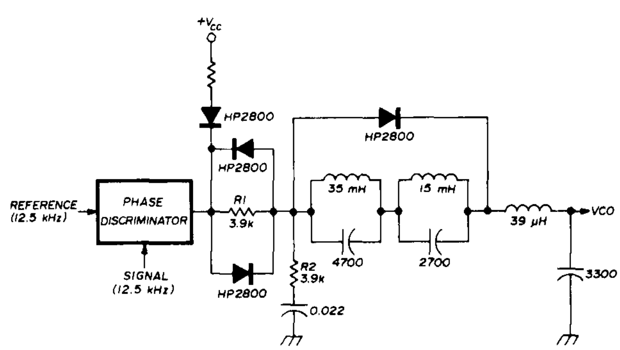
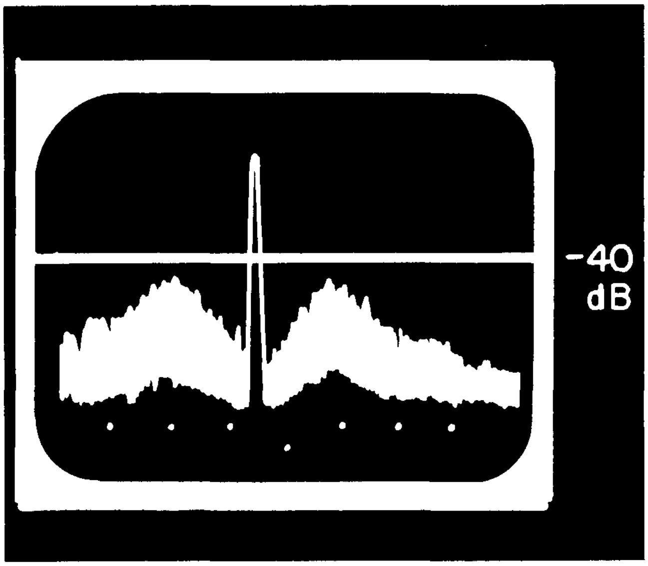


fig. 19. Frequency response filter for synthesizers using a lag filter, two LC tuned circuits as notch filters, and diodes for automatic selection of wider search bandwidth.



Phase-locked loop with a very noisy vco. Loop bandwidth is about 15 kHz within which the sideband noise is improved, as described in the text. Outside the loop bandwidth, noise increases then decreases; however, sideband noise remains at about 90 dB/Hz. Reference line is 40 dB; frequency markers are spaced 10 kHz.

For synthesizers with extremely low sideband noise, an improved version of a circuit similar to a balanced mixer is used. This circuit avoids spikes (in the order of 1 mV in magnitude) which are found in cascaded sample-hold discriminators. To minimize the influence of these spikes, a coarse presetting of the vco is often used, which results in a 20 dB improvement. However, if sideband noise suppression greater than 130 dB/Hz is required, this circuit is still not sufficient.

Fig. 18 shows an arrangement that requires a substantially larger number of components but which provides superior performance. The programmable-divider output (using 100-kHz channel spacing) is differentiated and amplified in transistor Q1. Diode CR2 across the unbalanced-to-balanced transformer provides a voltage similar to a sawtooth waveform. The RC combination R6, C7 and R7, C8 permits the dc voltage to rise to 30

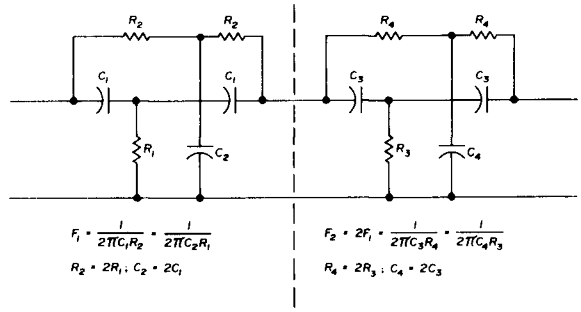


fig. 20. RC twin T-notch filter and the formulas for calculating frequencies.

volts maximum. The 100-kHz TTL reference triggers the one-shot formed by transistors Q4, Q5, and Q6.

The output of this circuit is fed into the center of the bridge of the "balanced mixer," represented by transformer T2. Voltage divider R18, R19 supplies a starting dc voltage, which is brought into the center of this bridge circuit. Transistor Q2 acts as a high-impedance source follower, and transistor Q3 acts as a low-impedance driver for the lag filter. The two back-to-back diodes, CR10 and CR11, are speed-up diodes; their function has been explained earlier. The dc output voltage for the vco contains substantially fewer spikes, and

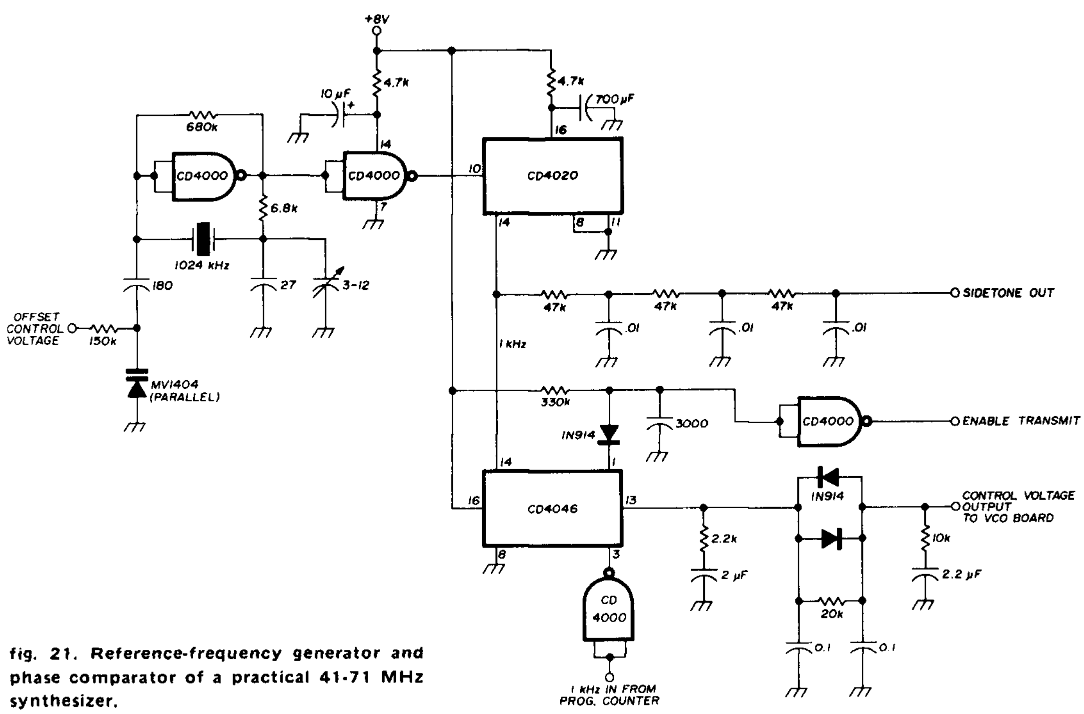


fig. 21. Reference-frequency generator and phase comparator of a practical 41-71 MHz synthesizer.

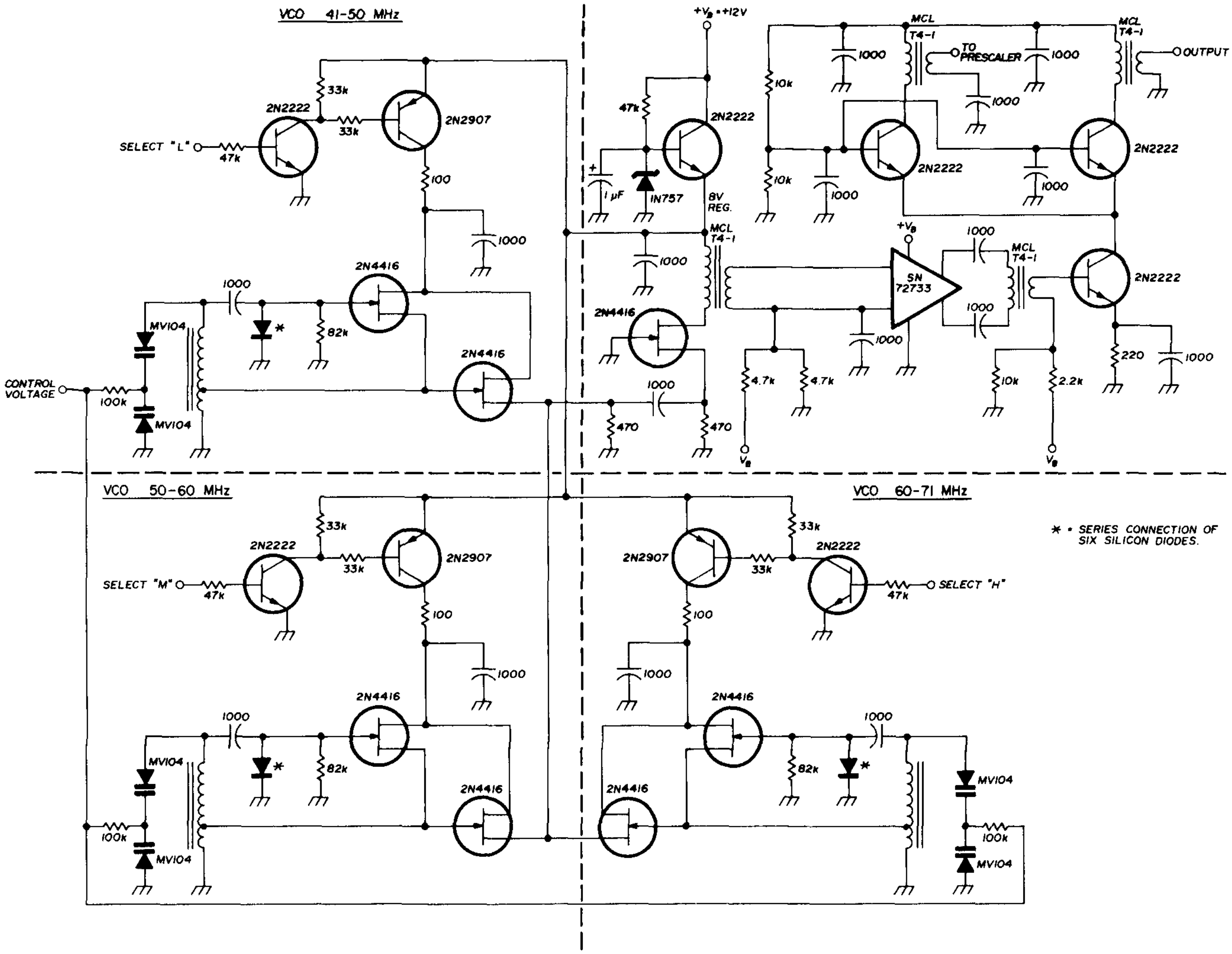


fig. 22. Three independent, low-noise vcos for the 41-71 MHz synthesizer.

the overall loop bandwidth can be made roughly 50% of the reference frequency and still support reference noise suppression. Most high-performance synthesizers on the market use a similar circuit.

response filters

Lowpass filters are required in phase-locked-loop circuits to limit system bandwidth for stable operation. A mathematical treatment of loop stability, as it can be done with the Nyquist diagram, is found in reference 9.

Lag filters are required to set the frequency performance. These lag filters depend upon the type of discriminator used. The Motorola handbook refers to active filter designs where the cutoff frequency is about 1% of the reference frequency. Let's assume that the reference frequency is 10 kHz. The flip-flop discriminator would require a bandwidth of 1% (100 Hz) for 3-dB cutoff. This means that the noise performance of the oscillator can be improved at best between 0 and 10 Hz. All microphonic effects, or sideband noise of the oscillator as such, will remain. In mobile equipment this is most undesirable, because all mechanical resonances will not be compensated.

When analyzing the circuits described in the Motorola handbook, it can be seen that not only are cutoff frequencies down to a few Hz used, but also that the additional transistors used as charge pumps will add noise to the system. Especially the so-called "flicker noise," which appears below 1 kHz, is a very unpleasant effect.

A sample-hold discriminator and the RCA edge-controlled digital memory do not give an output ripple when locked and no shift occurs; therefore, the loop bandwidth can be 20 times wider. In this case, compensation of microphonic effects up to several kHz is available.

As mentioned earlier, in some cases for signal generators, it is only required to synchronize them rather than improve them. The switching speed will then be very slow; e.g., 100 milliseconds. In some cases, as with digital sweeping, this is much too slow. To increase the speed, the filter bandwidth can be increased until the loop has settled. An easy way of doing this is to use two back-to-back diodes across the lag filter. This technique was suggested by Rohde & Schwarz many years ago; however, it is rarely found in the literature.

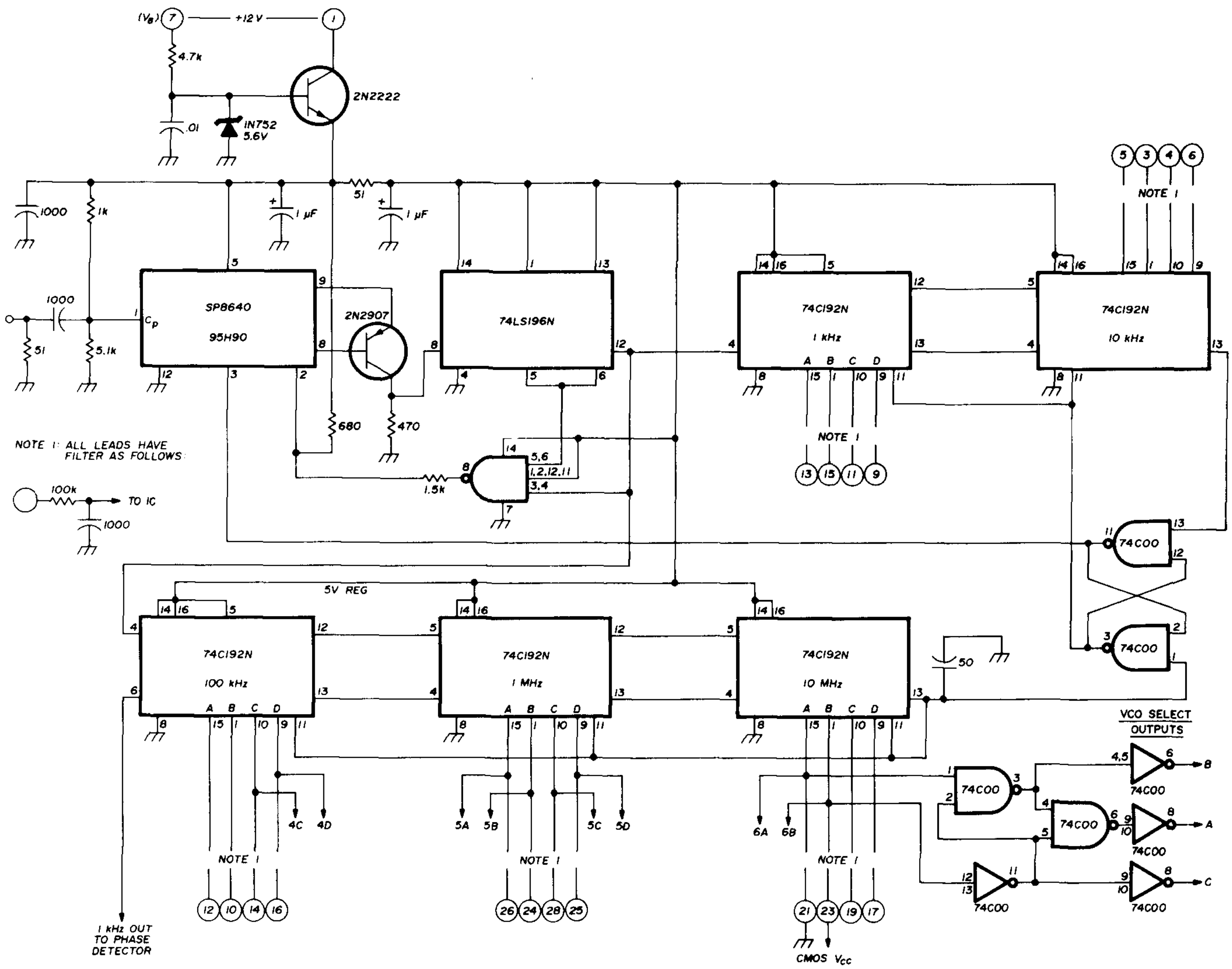


fig. 23. Programmable counter for the 41-71 MHz synthesizer.

If the phase/frequency comparator is in the search mode, the output is a dc voltage with an ac component. This ac component opens both diodes and short circuits resistor R1, which determines the low-frequency time constant. After the loop has settled, the diodes will no longer conduct.

An additional means of suppressing the undesirable reference noise is by using notch filters. **Fig. 19** shows a notch filter with two back-to-back diodes with a series resistor for automatic change of time constants.

A modified Wien-bridge arrangement acting as a T-notch filter can be used to suppress the reference frequency. Together with the RCA integrated circuit or with the sample-hold discriminator, the T-notch filter provides an additional 40 dB suppression. It is highly recommended that two T-notch filters be used, one for the fundamental frequency and one for the first harmonic (10+20 kHz). **Fig. 20** shows such an arrangement. It is also possible to use an LC notch filter for selective suppression, as shown in **fig. 19.**

practical circuit

Figs. 21 through **23** show a complete 41-71 MHz synthesizer that produces steps of 1 kHz. (Using a D/A converter, or better yet, a simple microprocessor, linear resolution can be gained, e.g., the reference frequency can be pulled in such a way that additional resolution, such as 100 Hz, 10 Hz, or 1 Hz, can be achieved).

Fig. 21 shows the reference oscillator and phase detector. A 1024-kHz series-resonant crystal is used, which can be set right on frequency with the variable capacitor. The gate circuit acts as an amplifier to produce an oscillator circuit that is decoupled from the reference divider, CD4020, by a gate. The MV1404 diode can be used for additional crystal-oscilllator frequency pulling.

The RCA CD4020 IC divides the crystal frequency to 1 kHz, and the input is fed to the CD4046 phase comparator, which was described earlier. In addition, sidetone output is provided and a lock-condition indication is available. The phase-comparator output, which drives the vcos (**fig. 22**), uses a lag filter with back-to-back diodes, as discussed earlier. The 1-kHz signal from the programmable counter is decoupled by a gate and fed to the phase comparator.

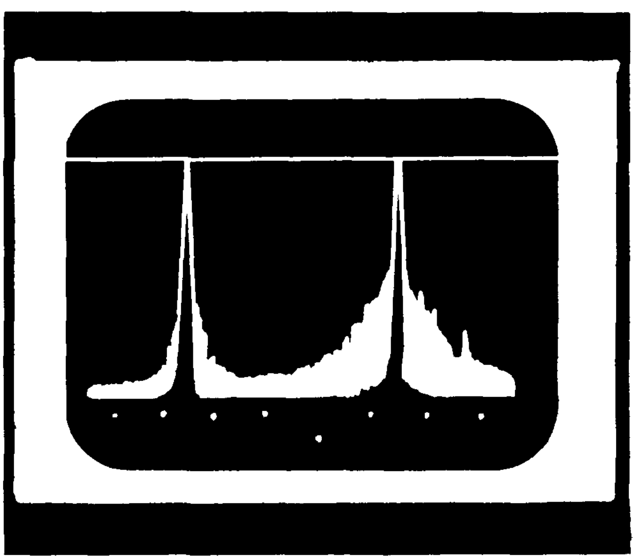
Fig. 22 shows the three independent, low-noise vcos whose outputs are selected by setting appropriate digits on a selector switch. The Texas Instruments SN72733 wideband amplifier is used for decoupling, and a cascade arrangement is used to provide two independent outputs at low impedance.

Fig. 23 shows the programmable counter. The 5 volts required for operation is derived from a simple regulator circuit. The input prescaler uses either the Plessey SP8640 or the Fairchild 95H90, which are pin compatible. The 2N2907 transistor is the ECL-to-TTL transverter. The gate between the 74LS196 and the 95H90, together with the 74C00 at the lower right-hand corner of the schematic, determine the count rate. All other integrated circuits are cmos to keep the power consumption low.

This synthesizer uses most of the techniques described earlier. Because of the back-to-back diodes, the lockup time is 6 milliseconds, and the loop bandwidth after the loop has settled is about 10 Hz. The 1-kHz reference noise is suppressed more than 80 dB and is therefore hardly detectable. This loop bandwidth cannot counteract any microphonics; however, because of its extremely good noise performance and fast switching time this synthesizer is ideally suited for use in a receiver with a first i-f at 41 MHz. Because it's a so-called one-loop synthesizer, it's basically spurious free and the reference noise, as mentioned earlier, is almost totally suppressed.

The total power consumption is in the order of 100 mA at 12 volts dc, and the synthesizer can be built on one PC board, requiring less space than half the size of a normal picture postcard. A very simple circuit, requiring only a few gates, can be built to subtract 41 MHz from the reading; the thumbwheel switches can then be directly calibrated to the receiver input frequency (see **fig. 24**). In this circuit the upper 74C83 receives the 10-MHz input which must be connected to pins 21 and 23 of the synthesizer input command. The lower 74C38 receives the 1-MHz steps and is connected to pins 24, 25, 26, and 28 of the synthesizer input command.

Comparison of two phase-locked-loop synthesizers with the same reference frequency. Output from balanced-mixer phase detector is shown at left, while the signal at right is from a loop using the technique suggested in the Motorola Phase-Locked-Loop Handbook. All other circuit details are the same. Reference is 0 dB, marker-frequency spacing is 10 kHz, and the carrier is about 150 MHz. Instrumentation used for all photos was the Rohde & Schwarz model EZF/EZFU spectrum analyzer.



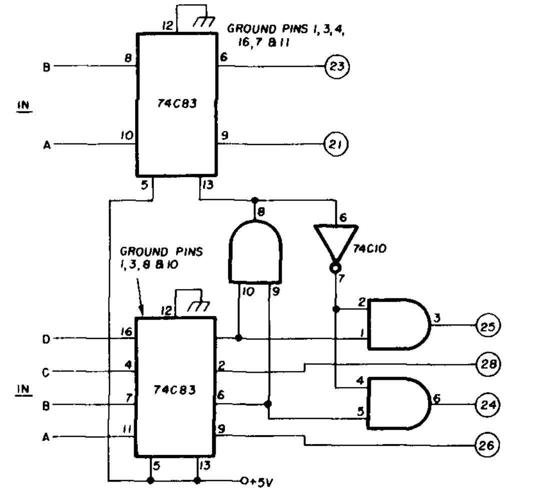


fig. 24. Simple circuit for subtracting 41 MHz from the synthesizer reading so the thumbwheel switches can be directly calibrated to the receiver input frequency.

It has been shown that today's technology permits building fast-switching synthesizers with low-noise and essentially spurious-free output at high frequencies. With new techniques and integrated circuits, these synthesizers consume little power, are physically small, and have high reliability. Especially, if cmos ICs are used, rf noise will be very low and almost no shielding will be required. A shortwave transceiver using a synthesizer based on these techniques will be described in a future article.

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ham radio

wind-generator

characteristics and installation techniques

Windblades and rotors are reviewed and an example is given of an amateur 200-watt electrical generating system

Many experiments have been made over the years with windmills and wind-rotating mechanisms. Several have been adapted as electrical-power generators. The theoretical maximum efficiency in converting wind power to torque at the rotor of a windmill is 59.3 per cent. Many rotating blades and other wind-driven configurations come rather close to this theoretical limit: within 5 to 8 per cent. The present direction of development involves economy in the support structure, gearing, generator, and other accessories. The objective has been to develop a strong, reliable, safe, lightweight, and economical support. Types of blades and rotors are significant in attaining these goals for a specific application.

Air is composed of gas molecules that have mass. Motion of these molecules is called wind. Upon striking a windblade, sail, or similar device, the wind imparts energy of motion. The efficiency of conversion depends on the design of the wind device. The force of such mechanical motion or torque made available at the rotor of a windmill depends on wind velocity, blade size and blade aerodynamics. Power made available varies as the square of the blade radius and the cube of the wind speed. For example, to quadruple the power output, it's necessary to double the blade radius. Doubling the wind speed results in an eight-fold power increase.

The equation that determines wind force in watts that impinges on a slim two-blade propeller is given by*

$$P = 0.005 A V^3 \text{ watts}$$

*When the blade rotational area, A, is in square meters, and wind velocity, V, is in kilometers per hour, the correct formula is:

$$P = 0.0129 A V^3 \text{ watts}$$

By Ed Noll, W3FQJ, Box 75, Chalfont, Pennsylvania 18914

where:

A = Area covered by the blade as it rotates (equivalent to πr^2), square feet
V = Wind velocity, mph
P = Power, watts

Table 1 presents as approximation of the useful power that can be derived from an efficient two-blade windmill in terms of wind velocity in mph (km/hr) and blade diameter in feet (m). An approximate overall efficiency

table 1. Output in watts for efficient two-blader.

blade diameter, ft(m)	wind velocity mph (km/hr) 10 (16)	15(24)	20(32)	25(40)
6 (1.8)	40	140	340	660
12 (3.7)	170	570	1350	2650
15 (4.6)	265	895	2120	4140
20 (6.1)	470	1590	3770	7360

of 30 per cent has been assumed, which includes gearing and generator. Not considered are additional losses in parts of the electrical system such as the charger, battery, distribution system, and inverter (if used). Shown is the relationship between power increases and blade diameter and wind speed.

windmill characteristics

Several characteristics describe the performance of windmills; here they are discussed in terms of two- and three-blade propellers. A simple two-blade arrangement, **fig. 1,** consists of blades, hub, and vane. Two blades are attached to a hub, which is fastened to the windmill rotor. The vane assembly keeps the blades pointed into the wind. To derive maximum benefit from wind power,

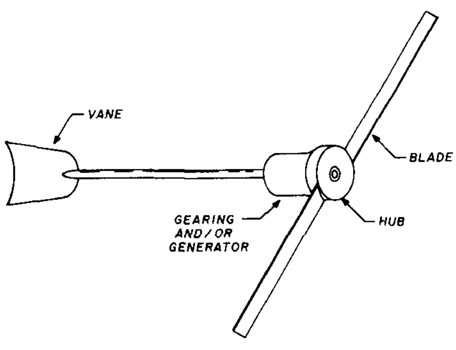


fig. 1. Basic elements of a wind generator.

the deviation from true orientation into the wind should not exceed ±12 degrees.

Another important factor is the blade pitch angle **(fig. 2A)**, which refers to the angle of the blade relative to the wind direction. When the relative wind velocity is in line with the blade element, no transfer of wind energy to torque occurs at the axle. For low-speed rotation of a multi-blade windmill, pitch angles of 30° and higher are used. For high-speed rotation, angles are substantially smaller. Small angles are required because the airfoils of many high-speed blades stall in the range of 12° to 14°. However, optimum pitch angle depends on application, desired operating conditions, type of

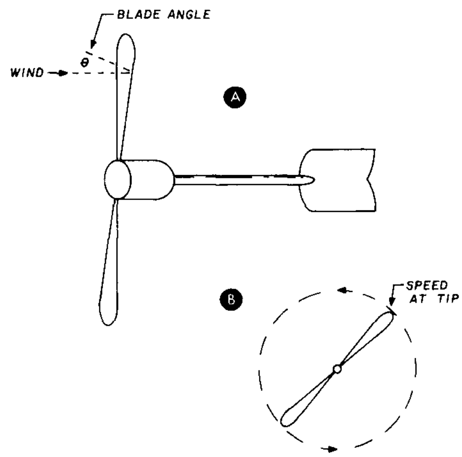


fig. 2. Pitch angle (A) and tip speed (B) of a wind-driven propeller.

blade, preferred angle of attack for blade air-foils, and the use of the wind-rotating system based on wind-speed limits at the site.

Windmills are sometimes classed as either low or high speed. In general a multiblade windmill rotates at low speed and is usually a heavy affair that develops high torque even in a light wind. It is widely used to convert wind energy to some sort of mechanical action such as running a water pump The high-speed windmill employs as few as two blades. It is lightweight and more adaptable to converting wind energy to electricity. Its high rotation speed is adaptable to low-ratio gearing of electrical generators.

Another factor of concern is tip-speed ratio. The tip-speed ratio, **fig. 2B,** is the ratio of wind velocity to tip rotational velocity. It is, in a practical sense, the ratio of wind speed to the speed of motion of the very tip of the blade. Tip speed is often stated as a whole number that compares the blade-tip velocity with the wind

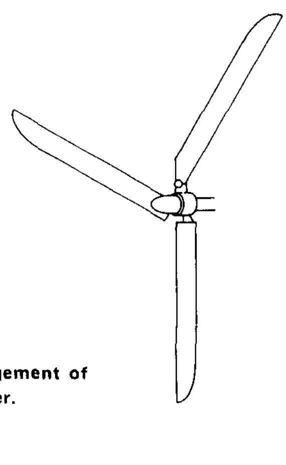


fig. 3. General arrangement of a three-blade propeller.

speed. A ratio of 4 indicates the propeller tip has a velocity four times faster than the wind speed. For electrical power generation, tip speed ratios under 4 are not recommended.

Lift-to-drag (L/D) ratio, another characteristic of concern, is an indication of how well the blade is turned by the wind relative to the torque or opposition offered by the propeller to being set into motion by a light wind. This ratio is related to blade construction, size and airfoil. Airfoil refers to the geometric shape of the blade. As in aircraft design, airfoil has a great influence on how well the blade can be turned by the impinging wind. A high-lift airfoil can increase the power output but also increases drag. Nonetheless, a high L/D ratio does permit higher output at a lower wind speed. Compromises must be made in establishing the preferred L/D ratio in terms of desired power output, weight, and wind-speed range over which the assembly is to operate at high efficiency.

For many low-powered applications a two-blade propeller is effective and efficient. However, in terms of weight and blade diameter, there is a practical limit to the size of a two-blade propeller. A three-blade propeller, **fig. 3**, provides additional power output as compared with a two-blade propeller and reduces periods of vibration with changes in wind direction as well. When the windmill orientation follows the tail vane, the resistance to orientation shift made by a two-blade propeller is in accordance with its position. When in a horizontal position this resistance is maximum. The net result is a jerking movement of the windmill as it follows a wind direction change. This action produces an undesirable stress when the blade is heavy or too large in diameter. Three- and four-blade arrangements present a steady resistance as the tail vane responds to a wind-direction change.

table 2. Power output of spoked-wheel as a function of wind velocity.

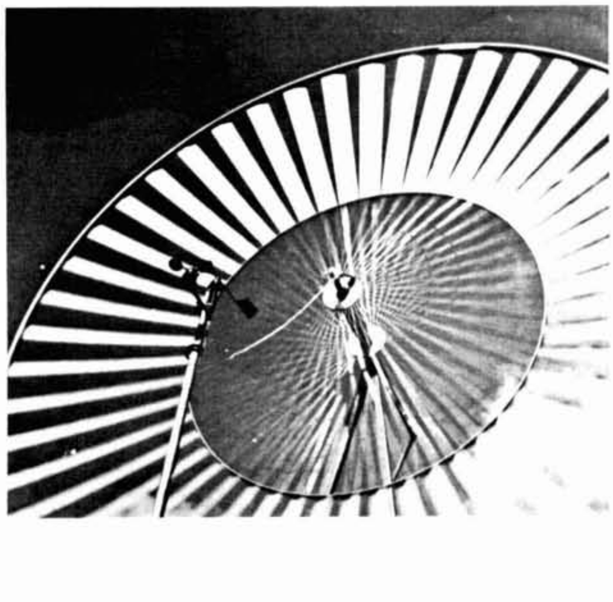
	wind speed, mph(km/hr)			wind speed, mph(km/hr)			wind speed, mph(km/hr)		
	10(16)	20(32)	30(48)	10(16)	20(32)	30(48)	10(16)	20(32)	30(48)
wheel dia., ft.(m)	horsepower			kilowatts			kW per month		
7.64(2.3)	0.147	1.18	3.98	0.077	0.615	2.08	55	443	1494
15.28(4.7)	0.589	4.71	15.91	0.307	2.460	8.31	221	1772	5979
30.56(9.3)	2.360	18.86	63.64	1.230	9.840	33.22	886	7087	23,919

Two lightweight rotators

The Chalk rotator, **fig. 4**, is unique, effective, lightweight, and starts easily in a light breeze. Early measurements indicate that it can reach an efficiency in the 50 per cent region (recall that theoretical maximum is 59.3 per cent). The Chalk rotator consists of a spoked wire wheel. The structure supports lightweight sheet-aluminum blades shaped in an appropriate airfoil section. The spoked wheel construction provides great strength despite its low weight. For example, a 15-foot (4.6m) diameter wheel weighs about 70 pounds (32kg).

An important advantage of the Chalk construction is that it simplifies gearing to a generator. As an option, it's possible to extract power at the rim. Since the wheel rim speed (comparable with the tip speed of a conventional blade) is high, it may be used to drive a generator directly or may use a very simple gearing system. In fact,

fig. 4. The Chalk rotator.



it's conceivable that the generator field poles themselves can be made part of the rim assembly. **Table 2** shows power output for spoked-wheel wind turbines at various wind speeds. Note that for a small (less than 8 feet, or 2.4m) diameter wheel, 77 watts are generated at a 10 mph (16 km/hr) wind velocity.

An advanced sail wing developed by Princeton University was conceived initially for boat application and eventually as an aircraft wing. Its structure is simple, lightweight, and efficient. Materials are inexpensive and permit a more simplified support structure than conventional blades. A sailwing consists of a rigid leading edge, **fig. 5.** The root section is attached to the rotor hub. Both tip and root are connected by a trailing-edge wire cable, which is fastened to a wraparound sail. The sail is cut in such a manner that its trailing-edge shape is set by the tension of the trailing-edge cable. A taut wing results, with a simple structure. However, the wing deforms and responds to loads in accordance with the wind velocity and angle, developing an effective aerodynamic characteristic. Of importance is its high lift-to-drag ratio. A lift coefficient and gentle stall characteristic compare favorably with the conventional hard wing and blade; it has the same load carrying capability. Furthermore it has the high efficiency of a sophisticated hard blade despite the favorable economics of its structure and support tower. In fact, its weight is such that a two-blade, 25-foot (7.6m) diameter blade is possible before dynamic effects become troublesome. For windmills larger than this diameter, three or more blades are advisable.

A study of wind conditions in the contiguous United States indicates that the maximum ratio between maximum and average wind is approximately 6. Since dynamic pressure increases as the square of the velocity (factor of 36), it's understandable that a windmill must be designed to withstand pressures many times greater that that exerted by the average wind at a given site The effect of strong winds is reduced by braking the windmill or by using a pitch-control system. The fact that the sail blade of the Princeton design is readily deformable results in a twisting component in high wind, which holds the rpm to a safe value.

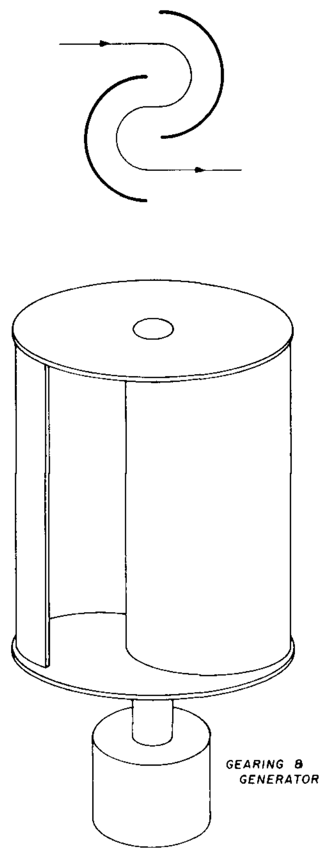


fig. 6. Savonius vertical S-rotor.

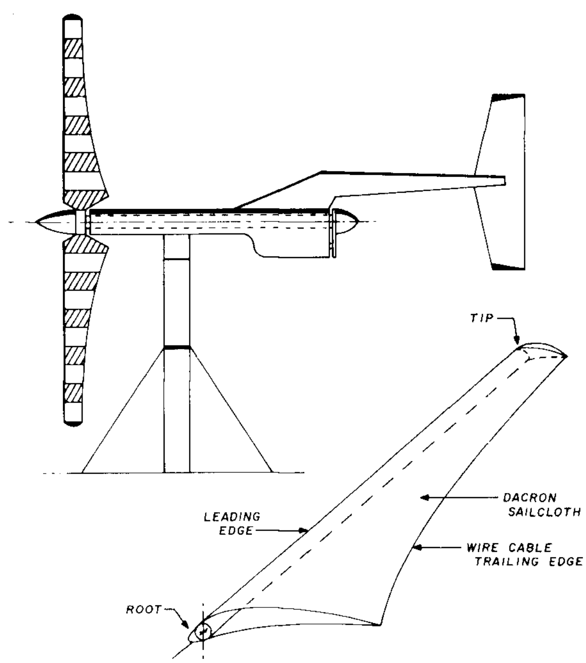


fig. 5. Sailwing generator developed by Princeton University.

The windmills described previously employ structures that rotate about a horizontal axis. Two plans that involve rotation about a vertical axis, although developed many years ago by Savonius and Darrieus (**fig. 6** and **7**), are being studied and experimented with today. Such rotors respond to wind pressure regardless of wind direction. No vane assembly is needed to orient them into the wind. In general complexity and maintenance are reduced using such a structure. Efficiency is good, and in an area subject to gusting and changing wind direction, output is steadier compared with the horizontal-axis rotor, which encounters loss time during intervals when it's being reoriented by the vane system to accommodate change in wind direction.

The Savonius or S-rotor is a drum-like configuration.* Air striking one of the concave sides of a two-blade arrangement is pressed through the rotor center vent to the back of the convex side, setting up the rotational

*A modified version of the Savonius rotator is sometimes seen on top of buildings where it's used as a ventilator. **Editor.**

pattern. It is a successful wind rotor but much is still to be learned about its characteristics. What is the most efficient and/or effective aspect ratio (ratio of height to diameter)? How does the shape, number of blades, and venting system affect operation?

Every indication shows that the Savonius has a high starting torque, which means that for a general applica-

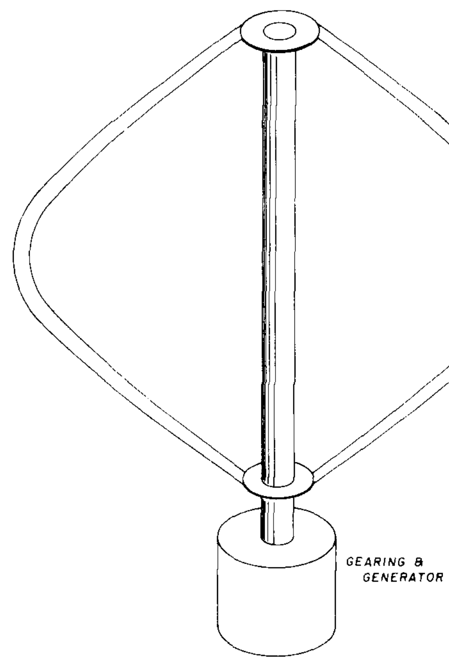


fig. 7. Catenary vertical rotator by Darrieus.

tion it will begin to rotate and generate energy at a lower wind speed. Rotation speed is slower but more power can be made available. The slow speed requires a higher gear ratio if the Savonius is to be used as a wind electric generator. However, the mechanical structure can be simplified because the generator can be mounted at the base using a long vertical shaft, **fig. 6.**

A primitive but very effective S-rotor can be made from discarded oil drums. These are halved and positioned off center. In its simplest form the drum is not reshaped and the venting system remains as is. However, higher starting torque and efficiency may be obtained by making changes to obtain a more ideal vent.

Considerable experimentation is being done with the Darrieus or catenary vertical-axis rotor, **fig. 7.** Tests with both two- and three-blade types are underway. Flexible airfoil blades are used in this construction. Under centrifugal and aerodynamic forces, the blades assume a catenary configuration (bulging at the equator and flattening at the poles). Extensive bracing is not needed and the supporting structure can be quite simple. Bearings at top and bottom and base-mounted gear and generator systems complete the basic structure. A guy-wire system provides additional support for the entire structure. In one experimental unit a 15-foot (4.6m) diameter blade generated 1 kilowatt at a wind speed of 15 mph (24 km/hr). At a wind speed of 30 mph (48 km/hr) the output increased to 8 kilowatts. As an aid during manufacture the blades were made of consecutive straight sections. Fastened together, a reasonable catenary shape can be synthesized. The catenary vertical axis rotor is not self starting. A starting vane or other arrangement starts the initial rotation of the catenary blades.

The vertical-axis wind generator, developed by Sandia Laboratory, combines the Savonius and Darrieus concepts to obtain self starting using a catenary vertical. Two three-bladed Savonius cups (starter buckets) at top and bottom of the power-generating catenary section, **fig. 8,** provide the high torque needed to start the rotating system in a light wind.

wind-generator installation

A 200-watt Winco* wind generator was installed at W3FQJ, **fig. 9.** The specifications of **table 3** indicate that in an area with a yearly average wind speed of 10 mph (16 km/hr) you can expect an average output from the generator of about 20 kilowatt-hours per month. This figure can be somewhat more or less depending on the season. Ten-year average monthly wind speed figures in mph (km/hr) for Philadelphia, Pennsylvania are:

Jan 10.3	(16.6)	July 8.3	(13.4)
Feb 10.8	(17.4)	Aug 7.7	(12.4)
Mar 11.8	(19.0)	Sept 8.0	(12.9)
Apr 11.1	(17.9)	Oct 9.0	(14.5)
May 9.6	(15.5)	Nov 9.2	(14.8)
June 9.0	(14.5)	Dec 9.6	(15.5)

In this area active winds occur in late fall, winter and early spring. Summer wind speeds are lower. Solar panel augmentation is advisable in planning a self-sufficient system. For most amateurs on-the-air activities are limited during the summer months. A 20-kWh-per-month rating at an average wind speed of 10 mph (16 km/hr) provides about 650 watts per day. Not too much power, but enough to run a 100-watt PEP solid-state transceiver almost continuously. Presently amateur radio station self-sufficiency in terms of power is no financial bargain, but it's a pioneering effort and encourages individualism.

As indicated in the specifications, the propeller is a wooden two-blade type, 6 feet (1.8m) in diameter. The propeller hub drives the generator directly; no belts or gear train are used. Generator rpm falls between 270-900 over a wind speed range of 7-23 mph (11-37 km/h).

The site for the wind generator at W3FQJ is on a small rise, reasonably in the clear, at the back of the house. The first step in the installation was the erection of the bottom section of the two-section 15-foot (4.6m) tower. Each leg is supported by a concrete base constructed by pouring concrete into a 2-foot (0.6m) hole dug with a posthole digger. Sixteen 2-foot-long (0.6m) threaded rods, 5/16-inch (8mm) in diameter, support the four base brackets of the tower.

The next step was to attach the wind generator to the top mast section. The top mast section houses a slip-ring

*Winco, Box 3263, Sioux City, Iowa 51102.

assembly that mounts on a platform, **fig. 10.** Hence the slip-ring and generator assembly rotate as the vane keeps moving the propeller into the wind. Slip-ring and contacts can be seen by opening the slip-ring case, **fig 11.**

The generator bracket is between two small knobs on the top of the collector-ring cover. This entire assembly was placed atop the lower mast section. Blade and brake

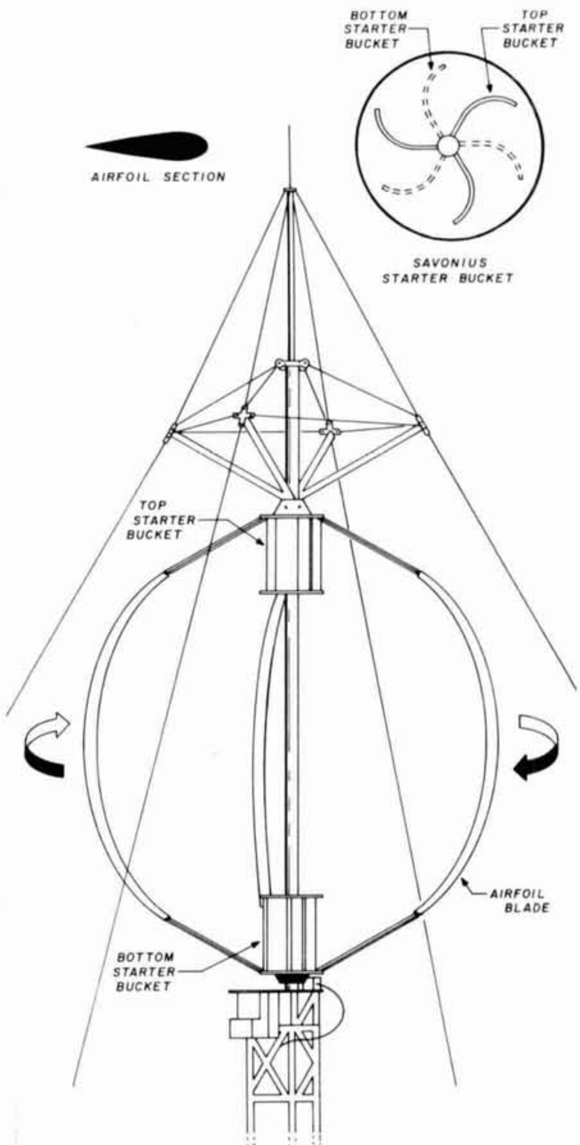


fig. 8. Vertical-axis rotator developed by Sandia Laboratories.

drum were then attached to the generator hub and the vane bolted to the rear generator bracket, **fig. 12.**

A mechanical governor controls rpm when the wind speed is greater than 28 mph (45 km/h), **fig. 12.** In normal winds the governor end plates follow a nonresistive circular path as the blades rotate in the wind. At high rpm the centrifugal force opens the end plates, and the resultant resistance holds down blade rotational speed.

A brake rod extends down through the slip-ring

table 3. Specifications for the 200-watt Winco wind generator.

Tower height	15 ft (4.6m)
Propeller type	2 blade
size	6 ft (1.8m)
material	wood
Gear ratio	direct
Generator	7½" (19cm) diameter
	4 pole
Capacity	200 watts
Approximate maximum amps	14
Approximate maximum volts	15
Generator	
Generator speed range	270/900 rpm
Governor type	22" (56cm) air brake
Propeller speed range	270/900 rpm
Wind speed range	7/23 mph (11/37 km/h)
Average usable kwh per month	
10 mph (16 km/h) average	20
12 mph (19 km/h) average	26
14 mph (22 km/h) average	30
Charge rates	
Revolutions per minute	Amperes
270	0
350	2½
440	6
570	10
700	12
900	14

assembly, and an extension of this rod can be used to brake the generator when desired. Pulling down on the rod causes the brake shoe to engage the brake drum. Braking is recommended when there is a possibility of winds higher than 75 mph (120 km/h). However, to minimize wear, the wind generator can be shut down when it's not being used to charge batteries. In fact, the wind generator should never be operated into an open

fig. 9. Winco generator and Solarex panel installation at W3FQJ.

circuit. A properly placed short circuit at the control box, **fig. 13**, can eliminate this possibility.

The generator can be used to charge lead-acid batteries, and with suitable circuitry, other types of batteries. One technique is to keep a high-capacity lead-acid battery under full charge and use it, in turn, to charge batteries of lower ratings. The manufacturer of the Winco generator recommends using a 230-ampere-hour battery, which can take good advantage of a sustained high-wind period to accumulate a full charge. If lower-rating batteries are used, care must be taken not to overcharge and you must be ready to change over among batteries.

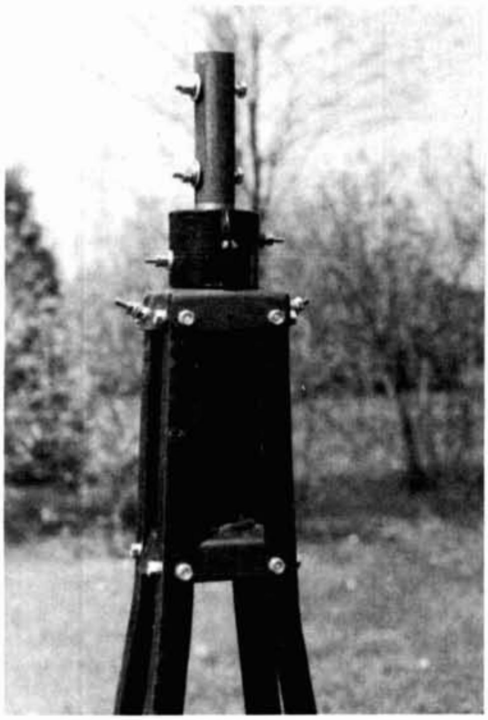


fig. 10. Top of tower section showing slip-ring assembly and platform.

In my installation, the generator is about 500 feet (152m) from the area where the batteries are located and my operating position. I use a small coaster wagon to carry batteries between generator and operating position. From the battery operating location a heavy-duty line runs into my office and electronics bench.

The new 6-volt Gel/Cel 20-ampere-hour batteries are ideal for operating small transceivers such as the Ten-Tec, **fig. 14**. These batteries are lightweight and can be right in the operating room or can be transported easily when portable operation is desired.

circuit description

The generator- and control-box schematic is shown in **fig. 15**. The generator is a brush type with a fixed field winding and a rotating armature. When the armature is turning, current flows from brush I through field coils D and C and back to brush H. Current is removed by the

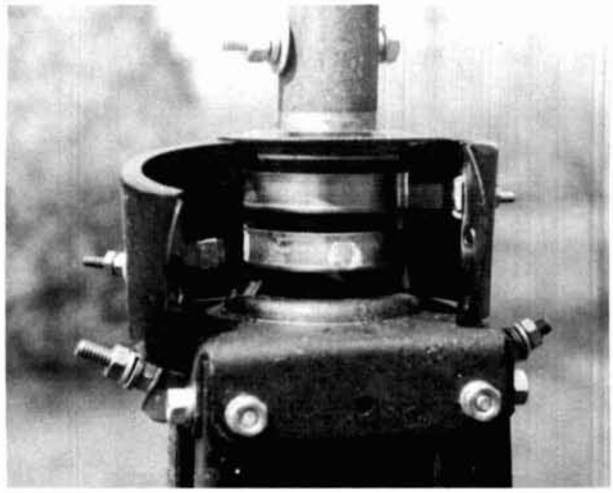


fig. 11. Open case showing slip rings and contacts.

pair of collector rings. Wires connect between the generator and the two terminals of the collector ring cover. These terminals can be seen in **fig. 10**. Internal connections are made between the collector rings and the two terminals fastened to the top of the tower. From these two terminals, wires are run to the control box. Two no. 10 AWG (2.6mm) wires are used for this connection because, in my case, the control box was attached to the

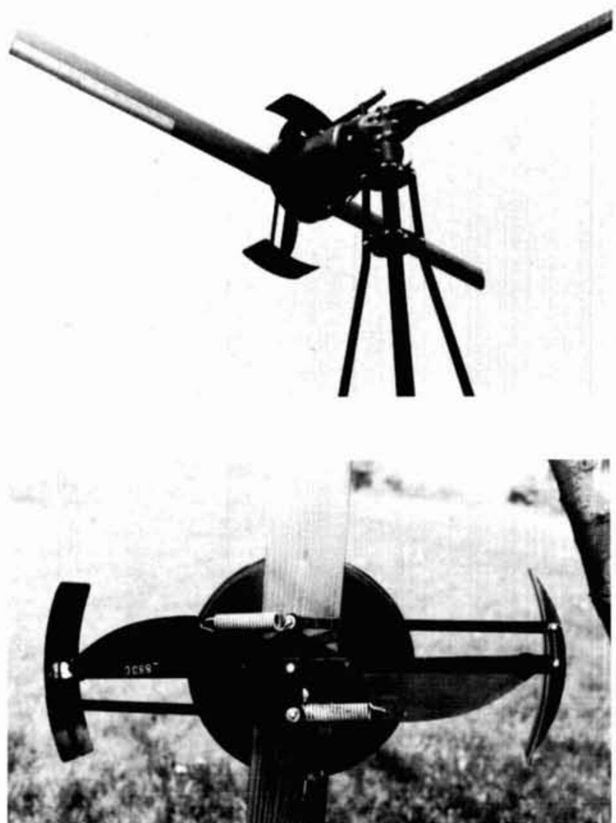


fig. 12. Completed wind-generator (top) and details of propeller-blade, brake-drum, and vane connections (bottom).

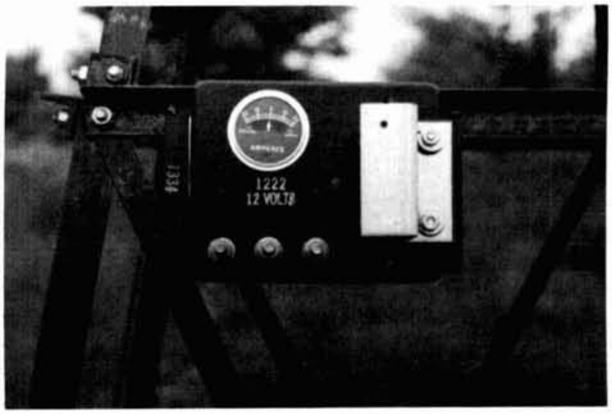


fig. 13. Control box attached to tower. Short circuit (right) is used to prevent system from operating into an open circuit with no load.

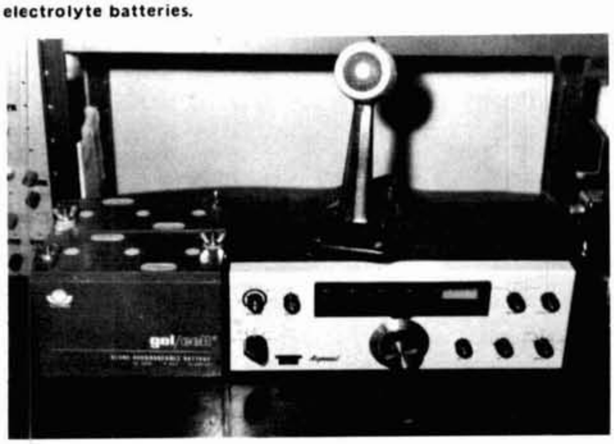
mast. If the control box is well separated from the mast, no. 6 AWG (4.1mm) wire is recommended for distances up to 50 feet (15m) and no. 4 AWG (5.2mm) wire for distances between 50-100 feet (15-30.5m). Longer distances require larger-diameter wire. You're working with low voltage and high current; therefore, wire resistance is a very important factor.

The control box houses a charge-discharge ammeter, diode and terminals. The diode prevents the battery from discharging through the generator. However, its polarization is such that charge current from the generator passes with no significant attenuation. The generator is, of course, a dc machine using rectification by brush and commutator. A scheduled-maintenance inspection of the brushes is recommended. Brushes should be replaced when worn.

Note from **fig. 15** that the plus side of the generator output connects to the *A-Gen* terminal of the control box. From here the path is through the diode and the ammeter to the control box *+Bat* terminal. The generator negative terminal connects to the control box *F-Gen* terminal. This is the negative side of the battery-charging circuit.

When checking out the wind generator a discharged battery should be connected between the *-Bat* and *+Bat*

fig. 14. Ten-Tec transceiver installation with 6-volt Gel/Cel dry electrolyte batteries.



terminals. The brake can be released and the blade allowed to rotate in the wind. The charging current will be indicated on the meter. In no wind, the circuit can be checked by "monitoring" the generator. In this operation the battery is connected and a short circuit is connected between points B and G (across the diode). This allows the battery current to flow in the generator, which operates as a motor and rotates the blade. In this case the ammeter will read on the discharge side

If the blade is to be rotated without any battery load, a short circuit must be connected between the control box *F-Gen* and *A-Gen* terminals. An open circuit is to be avoided because it results in high voltages appearing in

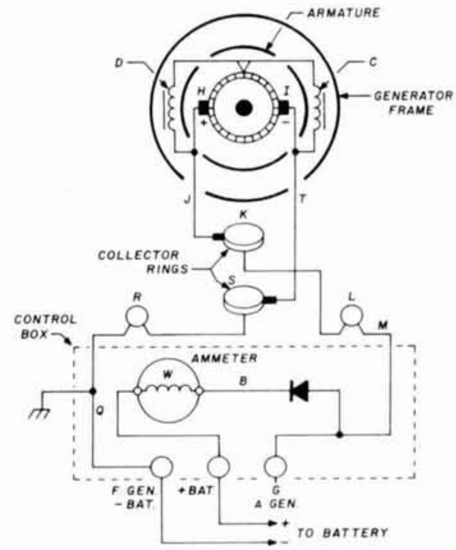


fig. 15. Wind-generator power-supply schematic. Wire size between generator, control box and batteries is important (see text).

the generator and arcing among commutators and brushes. The generator produces a charging current at 7 mph (11 km/h), reaching a maximum in a wind speed of 23 mph (37 km/h). Governing action begins at 28 mph (45 km/h).

Charging current varies with the wind, so it's difficult to keep a charge record unless an ampere-hour meter is inserted in the charging circuit. Therefore a hydrometer is essential in determining when a given battery is fully charged.

As shown in **fig. 9** a Solarex* solar panel has been attached to the south side of the tower. This is a 6-watt unit that provides a ½-ampere trickle-charge current. Thus during periods of daylight no-wind conditions a trickle charge can be maintained. A separate control box is being constructed for this panel.

A "much obliged" is extended to Richy Atkinson WA3KHM, Bob Bucher WA3KMW, (now deceased), Heinz Frey, WA3DNZ, Harry Mullen, WA3RLI and Dick Wagner, who aided in the wind generator project.

ham radio

*Solarex, Corporation, 1335 Piccard Drive, Rockville, Maryland 20850.

how to add an inverted V or delta loop to your tower

An easy way to obtain low-angle coverage for 40, 80 or 160 meters using a simple mast extension on your high-frequency beam antenna installation

Over the past few years, and especially since the introduction of the 5BDXCC and 5BWAS awards, numerous articles on antenna systems for 80 and 40 meters have appeared in the amateur magazines. These systems were basically trying to accomplish one purpose: a lower radiation angle on these bands. All too often, however, impractical heights or a considerable amount of real estate were involved.

Presented here is an inexpensive means of extending the height of your tower so you can mount one of the popular inverted-vee or "drooping dipole" antennas for the lower frequencies. The only requirement is a tower of some height with the antenna rotor installed inside the tower.

description

The basic idea is a mast extension at the top of your tower. To this extension a swivel joint is affixed. Above the swivel joint, another 6 to 12 inch (15-30 cm) length of identical mast is mounted, which acts as a mounting base for a low-frequency antenna. A typical setup is shown in **fig. 1**. When erected as shown, everything below the swivel rotates when you rotate your beam. Antennas for 80 and 40 meters, or for that matter, any bands you wish, then serve to guy the installation and keep the short section of mast above the swivel from rotating. Simple? You bet! The cost for the entire assembly, not including antennas, will be less than $20.

design considerations

The upper mast extension is needed so your beam element ends will clear the low-frequency antenna (or antennas) as the beam antenna is rotated. The mast extension length depends on the size of your beam antenna. A typical tribander, such as the Classic 36 or TH6DXX, will require a minimum extension of about 22 feet (6.6m) above the plane of the elements. This is the minimum extension. In practice, about a foot (30cm) should be added to allow for ample clearance. Dimension X in **fig. 2** is the minimum value that will allow the beam antenna to turn freely under a low-frequency wire antenna drooped 45 degrees from the horizontal. Dimension X is determined by simple geometry:

$$X = \sqrt{Y^2 + Z^2} \qquad (1)$$

where X is the clearance height, Y is the distance from the rotator mast midpoint to the end of the boom, and Z is the distance from the boom end to the end of the longest element. Remember that dimension X is the

By Ed Sleight, K4DJC, 4165 Williamsburg Drive, College Park, Georgia 30337

minimum value needed to clear your beam antenna; it's not the maximum value for the mast extension.

construction

The mast extension was made of ordinary *heavy-duty* TV mast, available in 5- and 10-foot (1.5 and 3m) sections. The longer sections are easier to work with and are recommended for the main part of the extension. A 5-foot (1.5m) mast section is best for building the swivel-joint portion. If three 10-foot (3m) sections and one 5-foot (1.5m) section are used, the extension gained will be about 30 feet (9m) above the plane of the beam elements. This will allow about 5 feet (1.5m) of the extension to be enclosed by the rotator mast. While probably feasible, extensions longer than 35 feet (10.6m) have not been tried here.

The swivel joint is the key to the whole system. It may be as simple or as elaborate as you wish. My first one was made with parts from an old tricycle. The latest model was made from a 0.75-inch (19mm) water pipe union joint (Sears part no. 42G 12673) and two short pieces of water pipe screwed into the union joint. The union was tightened snugly, while allowing it to still rotate, then it was secured with a sheetmetal screw to prevent further movement. The water pipe sections, each about 1 foot (30cm) long, were then built up with pieces of aluminum scrap tubing until a force fit was obtained inside the 5-foot (1.5m) mast section.

installation

My low-frequency antennas are fed with baluns. I believe in feeding a balanced antenna with a balanced feed system. The baluns are easily attached to the short section of the swivel and serve nicely as attachment points for the antenna wires. They will also keep the low-frequency antennas separated at the top of the extension. Tape the feedline securely to the sides of the mast extension. This will keep the weight of the feedline more along the centerline axis of the mast and prevent excessive bowing as the mast is raised.

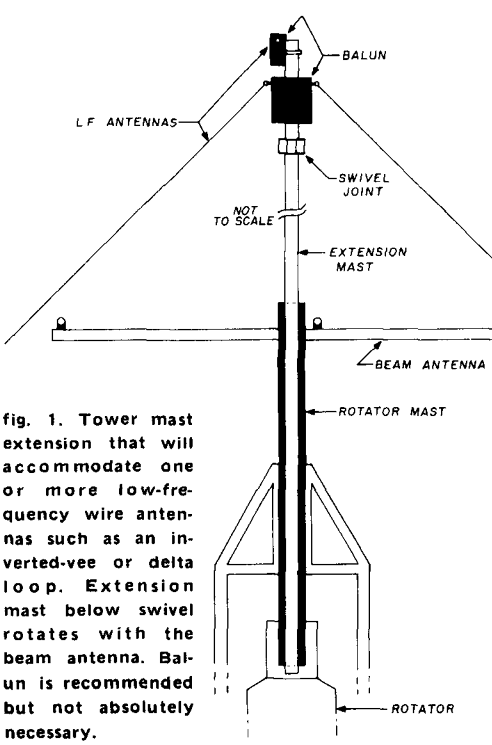


fig. 1. Tower mast extension that will accommodate one or more low-frequency wire antennas such as an inverted-vee or delta loop. Extension mast below swivel rotates with the beam antenna. Balun is recommended but not absolutely necessary.

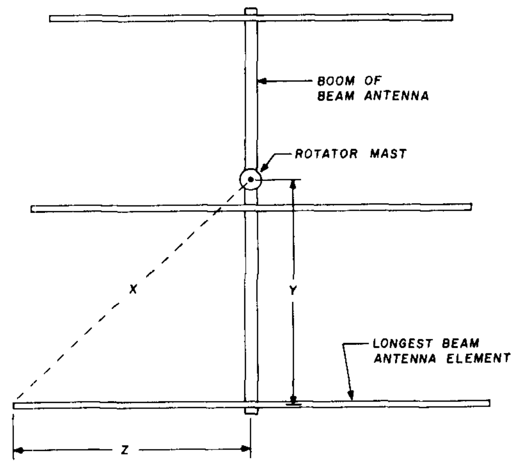


fig. 2. Geometry for determining minimum (see text) clearance of wire antenna that will allow beam antenna to turn freely.

The assembly is easiest to erect if all masting is placed inside the tower, then joined in proper order and fed out the top of the rotator masting. This will usually require removing the rotator. Since the swivel joint will most likely not pass through the rotator mast, it should be fitted in place (with all antennas attached) as the next lower section of masting is pushed upward. Continue feeding the mast extension out the top. When fully extended, secure the base of the extension. I do this by just slipping the rotator back into place.

Tie off the ends of the antennas to obtain the best vertical positioning of the extension mast. Don't worry if the mast leans or bends over slightly while it's being extended. When fully erected, the wire antennas do double duty as guys.

performance

If your tower is in the 50 to 60 foot (15-18m) range, you'll probably have a couple of inverted-vee antennas tied off below the top. With this mast extension, the *high-current portion* of your antennas will be about 80 to 90 feet above ground (24-27m). On 40 meters, this will lower your radiation angle from about 35 to around 20 degrees.

If your present system is in the 50 to 60 foot (15-18m) range, most of your 80-meter signal will radiate straight up. The system described here will lower that radiation angle to around 45 degrees.

ham radio

JULY 2

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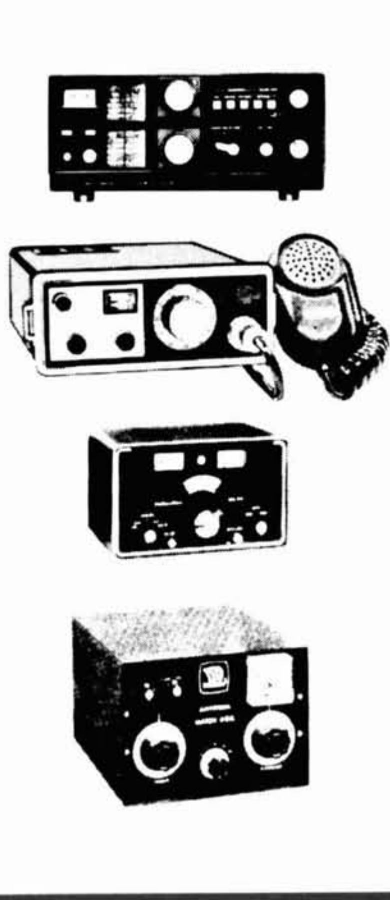

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HAMTRONICS

five-frequency receiver for WWV

Design and construction of a frequency-standard receiver using a modified transistor broadcast set and an fet converter

For those amateurs whose receivers lack WWV reception, a separate frequency-standard receiver is a useful addition. The special-purpose receiver described here receives WWV on 2.5, 5, 10, 15, and 20 MHz which covers all WWV transmissions except 25 MHz. The receiver gets all of WWVH's transmissions, since WWVH doesn't transmit on 25 MHz.

A block diagram of the receiver is shown in **fig. 1.** The system consists of a modified transistor broadcast receiver and a converter. The transistor radio operates "straight through" for 2.5-MHz reception and serves as an i-f amplifier for the converter, which tunes the higher WWV frequencies. Two crystal oscillators are required, one at 7.5 and one at 17.5 MHz. Each local-oscillator frequency allows dual-frequency reception of WWV, because 10 MHz and 20 MHz are the respective image frequencies when receiving 5 and 15 MHz.

broadcast receiver

The 2.5-MHz section, consisting of a transistor broadcast radio, requires a slight modification to the antenna tuned circuit to make it a fixed-tuned 2.5-MHz amplifier. The modification is simple, because almost all transistor broadcast sets use high-side mixing; i.e., the local oscillator is 455 kHz higher than the received frequency. This means that when the radio is tuned to 1590 kHz, its local oscillator is at 2045 kHz, and the image frequency is 2.5 MHz. Thus 2.5 MHz is easily received by retuning the broadcast radio's antenna tuned circuits to 2.5 MHz. I didn't want the loopstick to function as a 2.5-MHz antenna when receiving other frequencies, so the loopstick was replaced with a small slug-tuned coil. Modification of the broadcast transistor radio is the first step, so it will be treated first.

The broadcast set I used was sold by Magnavox, uses six pnp germanium transistors, and was apparently made in Japan. Newer sets may use npn silicon transistors, and some older GE sets may use npn germanium transistors; however, the conversion will be similar. A typical six-transistor receiver is shown in **fig. 2.**

Tune the receiver to 1590 kHz, remove power, then replace the loopstick antenna (L7 in **fig. 2**) with a slug-tuned coil (L6 in **fig. 3**). Note that the new coil has both primary and secondary windings, so problems of dc isolation are simplified between the broadcast receiver and the rest of the system.

receiver front end

The WWV receiver front end is shown in **fig 3.** Note the use of field-effect transistors. Dual-gate mosfets are used in the rf and mixer stages, while a jfet is used for the crystal-controlled local oscillator. Using dual-gate mosfets as rf and mixer stages simplifies matters, because in each case one gate can be used as a signal-input port and the other for gain control or local oscillator input.

The jfet makes a simpler crystal oscillator than a mosfet because it has a built-in gate-to-source diode, which rectifies oscillator rf voltage and acts much the same as the grid-cathode diode in a vacuum-tube oscillator in establishing grid-leak bias.

The band switch is a five-pole, five-position wafer switch. In the 2.5-MHz position, S1 disables the crystal oscillator and mixer so that only the rf amplifier and the transistor radio are used. Note that L6 is part of a 2.5-MHz parallel-tuned circuit, which is the load for the drain of the mixer fet when the receiver is tuned to 5, 10, 15, or 20 MHz. When the receiver is on 2.5 MHz, L6 becomes the load for the amplifier drain (by means of S1D and S1E). It is for this reason that L1B does not exist.

Rf gain may be adjusted by a 10k pot that varies the voltage on gate 2 of Q1 from zero to +3 volts through a

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100k resistor. If agc is desired (not included here because it's not known what transistor radio the reader may start with), it would be fed into gate 2 of Q1 through the 100k resistor. The agc would vary this voltage from zero (minimum gain) to about +3 volts (maximum gain), with variations in signal level.

power supply

A regulated power supply for the WWV receiver is shown in **fig 4**. A three-terminal IC regulator provides +12 volts for the front-end section, and a simple emitter-follower regulator provides +9 volts for the converted broadcast receiver. Some transistor broadcast radios operate on 4 volts (a mercury battery) or even on 6 volts (four penlight cells); it's possible to accommodate these by using a different voltage-breakdown zener in place of CR3. The zener voltage should be close to 0.6 volt more than the desired output voltage of the emitter-follower regulator. A 4.7-volt (HEP Z0405) zener for 4-volt output and a 6.8-volt (HEP Z0409) zener for 6-volt output would be appropriate.

construction

The receiver was built in an LMB W1A box. Looking at the front panel, the power transformer and modified broadcast radio are on the top side of the subchassis at the left. The transformer is the only part of the power supply on top of the subchassis; the rectifier and regulator are on the underside of this subchassis. The broadcast radio (actually its PC board without plastic case) is mounted on the top side of the subchassis. Three or four ¼-inch (6.4mm) fiber or plastic spacers were used in mounting to avoid shorting out PC-board traces. The speaker was remounted on the W1A box front panel (using an appropriate hole size and a piece of perforated metal grille material). Also mounted on this front panel is a volume-control of the same value as that contained in the transistor radio. This control was wired into the radio in place of the original, which was left undisturbed. The original volume control could have been used but wasn't suitable for panel mounting.

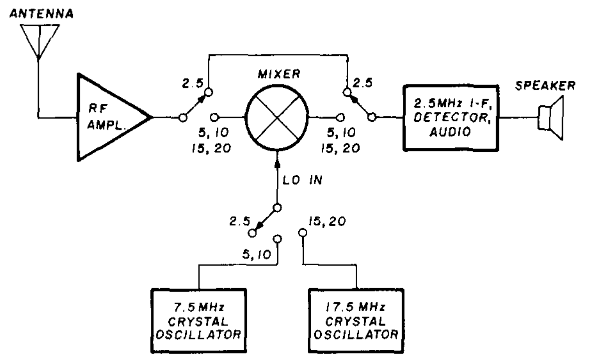


fig. 1. Block diagram of the five-frequency WWV receiver. A transistor broadcast radio operates as a fixed-tuned receiver for 2.5 MHz and as an i-f amplifier for the higher WWV frequencies.

On the right side of the subchassis, a 3¼ x 4¼-inch (82.6x108mm) hole was cut, and a 3-3/4 x 4-7/8-inch (95.3x124mm) piece of dual-sided copper laminate PC material fitted over it. This piece of PC material was secured to the subchassis by six 4-40 (M3) screws. It's far easier to construct rf circuitry on the PC laminate than on the aluminum subchassis, as grounds can be made easily and directly by soldering.

Most front-end circuitry is located on top of this piece of PC board. the main exceptions are the two crystals and coils L2B, L3B, L4B, L5B. These coils should be mounted on the opposite side of the board from L2A, L3A, L4A, L5A to avoid inadvertent coupling and possible oscillation in the rf stages. Because of this simple inductance-isolation method, no further shielding partitions were needed.

The front-end bandswitch was made from a Centralab type PA301 wafer switch with three PA3 sections spaced 1¼-inches (31.8mm). The rf amplifier is located next to the rearmost switch section, the mixer next to the center

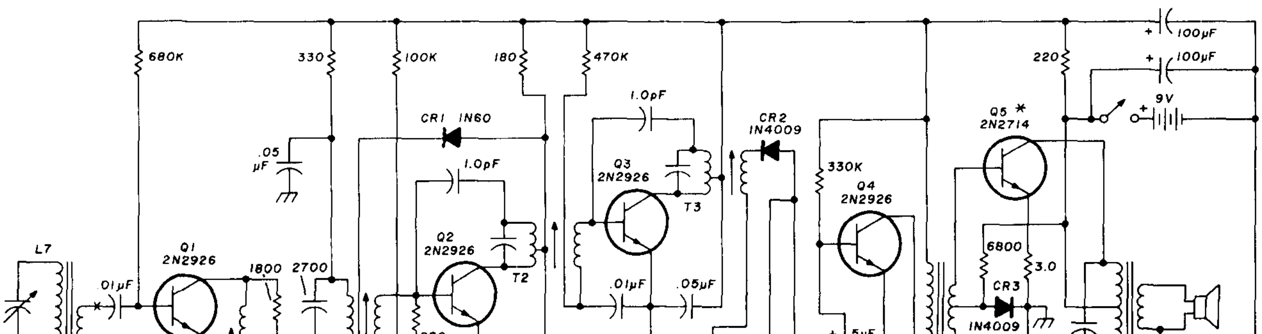
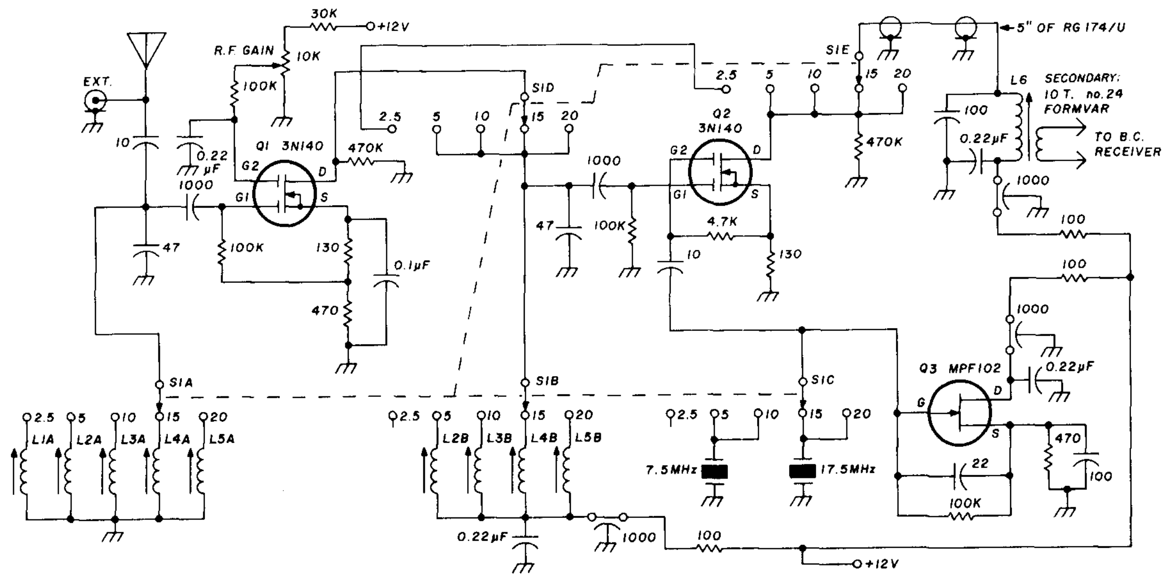


fig. 2. Schematic of a typical six-transistor broadcast receiver used in the WWV receiver design. Coil L7 was replaced by rf transformer L6 in fig. 3.



L1	61 - 122 µH (Cambion X2060-7)	L5	0.83 - 1.6 µH (Delevan 4000-10)
L2	10 - 18 µH (Cambion X2060-4)	L6	28 - 63 µH (Cambion X2060-6), *10 turn secondary*
L3	2 - 3.7 µH (Cambion X2060-1)	Q1,Q2	3N140, MFE3006, HEP F2004, RCA 40673
L4	1.3 - 2.5 µH (Delevan 4000-12)	Q3	MPF102, HEP802, HEP F0015

fig. 3. Converter for the WWV receiver. Dual-gate mosfets are used for the rf and mixer stages; the local oscillator uses a jfet, which has a built-in gate-to-source diode that rectifies rf voltage.

switch section, and the oscillator next to the front section. Coil L6 is on top of the laminate immediately behind the volume control and to the side of the mixer.

The three +12 volt lines (one each for rf, mixer, and crystal oscillator) emerge through the copper laminate through small 1000 pF feedthrough capacitors, with the 0.22 µF bypass capacitors on the top side. The 100-ohm decoupling resistors are located on the bottom. I strongly recommend that all bypass and coupling capacitors (1000 pF, 0.1 µF, and 0.22 µF) be ceramic disc or Erie *Redcap* types. These have both high capacitance and low inductance for broadband rf use. The smaller capacitors (10 pF - 100 pF) should be silver-mica.

If the older types of dual-gate mosfets such as 3N140 or MFE3006 are used (which have no gate-protection diodes), the transistors must be handled with the usual precautions. That is, a small no. 32 AWG (0.2mm) bare wire must short all four leads until they are soldered into the circuit. The 470k resistor from each drain of Q1 and Q2 ensures that, during band switching, some dc resistance is always between all elements of each mosfet.

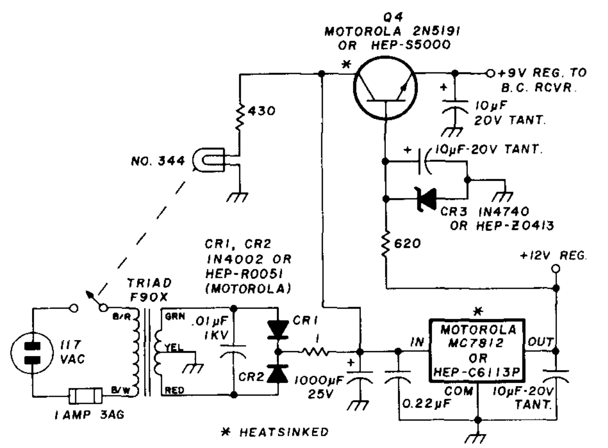


fig. 4. Regulated power supply for the WWV receiver, which provides +12 volts for the converter and +9 volts for the converted broadcast radio. Other transistor radios can be accommodated by using a different zener in place of CR1. The MC7812 voltage regulator IC is heatsinked directly to the chassis. Transistor Q4 is mounted on chassis with mica washer and silicone grease.

tune up

Tuning the receiver is simple, especially if you have a good signal generator. With the broadcast radio tuned to 1590 kHz, inject a 2.5-MHz signal into the WWV receiver (bandswitch on 2.5 MHz) and maximize the broadcast receiver output near 1590 kHz. Then adjust L1A and L6 for maximum output. Next switch to 5 MHz and peak L2A and L2B; in a similar manner, maximize L3A and L3B on 10 MHz, L4A and L4B on 15 MHz, and L5A and L5B on 20 MHz.

The receiver is designed to use a short piece of wire as an antenna. With a standard 50-ohm generator connected (mismatched) to this antenna, signals of 1 microvolt (1000 Hz, 50% modulated) could be easily detected on all five bands.

references

1. Jim Ashe, W1EZT, "WWV Receiver for $5," *73*, November, 1966, page 20.
2. C. Caringella, "Build a Three-Channel Time Receiver," *Popular Electronics,* December, 1970, page 33.

ham radio

More Details? CHECK—OFF Page 118

shirt pocket transistor tester

The transistor tester described here is useful when troubleshooting circuits. It's also great to take along while shopping the surplus stores for checking unknown devices. Large quantities of older transistors are available at low cost in surplus outlets, many of which are entirely suitable for many projects.

This tester will allow you to grade devices into npn/pnp and good/bad categories. It will also give you a pretty good idea as to whether the transistor is germanium or silicon. The best way to illustrate what the tester can do is to go through a typical test routine. The following procedure is based on the fact that the loaded terminal voltage of the battery in the tester is at least 7.5 volts.

using the tester

Suppose you wish to test a small-signal transistor that has no recognizable markings. Before plugging it into the tester, make sure the function switch is at the *short* position. This test must *always* be made first. Since nothing is known about the device, either npn or pnp can be chosen on the toggle switch. If the meter shows any reading at all, you'd normally reject the transistor without making any further tests. In this case however, if the toggle switch were set to npn and the device under test was a pnp (or vice versa), the meter would indicate a short circuit. (More about this later.)

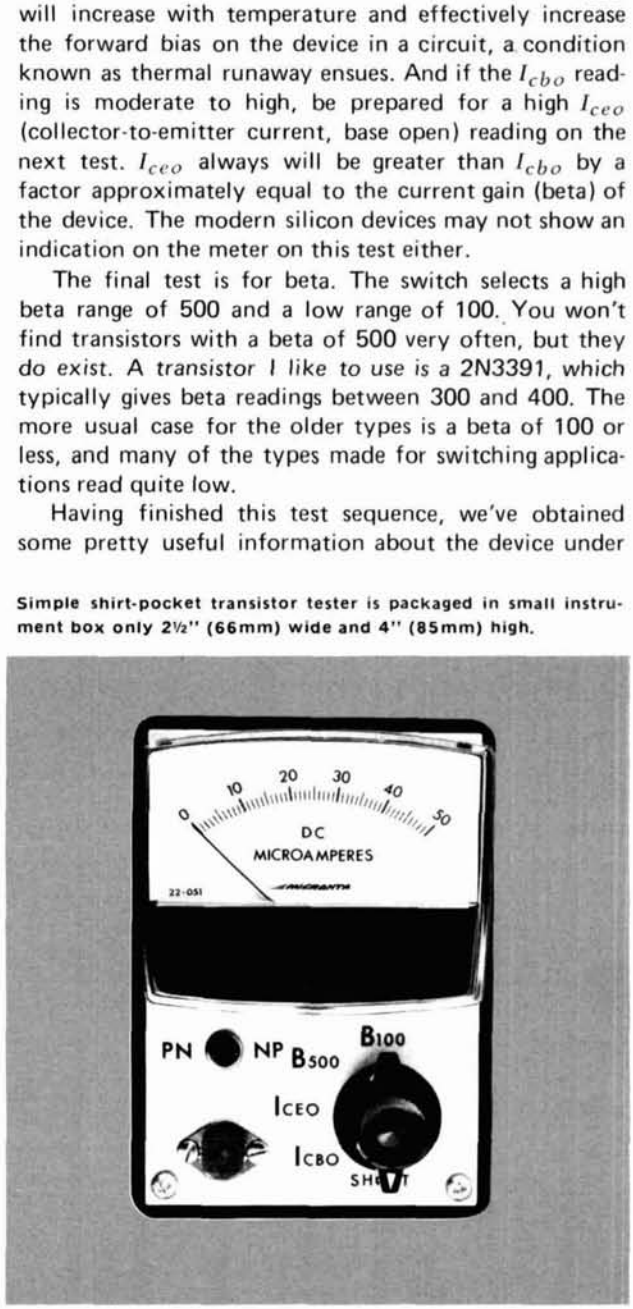
Move the toggle switch to its other position and check for a meter reading. If the meter still deflects, we no longer care what the device is because it's definitely bad. Do not attempt to make any other tests on a bad device; it's bad for the meter! If the meter reads zero, then we've determined the device type and the fact that it's probably usable. The second step is to determine the quality of the device.

Turn the knob to test for I_{cbo} (collector-to-base current, emitter open). Most modern small-signal transistors exhibit nanoamperes of I_{cbo}. Many older types have microamperes of I_{cbo}. The former will give little or no reading on this meter, while the latter will produce small to moderate readings. We'd normally relegate a transistor with a high I_{cbo} reading to the trash can or give it to some curious youngster, so further testing at this point is really academic. In any case, a transistor that produces a moderate-to-high meter reading is probably a germanium device. Germanium devices typically have I_{cbo} values 10 to 100 times that of silicon devices, which is one reason why most transistors made today are silicon. Since I_{cbo} will increase with temperature and effectively increase the forward bias on the device in a circuit, a condition known as thermal runaway ensues. And if the I_{cbo} reading is moderate to high, be prepared for a high I_{ceo} (collector-to-emitter current, base open) reading on the next test. I_{ceo} always will be greater than I_{cbo} by a factor approximately equal to the current gain (beta) of the device. The modern silicon devices may not show an indication on the meter on this test either.

The final test is for beta. The switch selects a high beta range of 500 and a low range of 100. You won't find transistors with a beta of 500 very often, but they do exist. A transistor I like to use is a 2N3391, which typically gives beta readings between 300 and 400. The more usual case for the older types is a beta of 100 or less, and many of the types made for switching applications read quite low.

Having finished this test sequence, we've obtained some pretty useful information about the device under

Simple shirt-pocket transistor tester is packaged in small instrument box only 2½" (66mm) wide and 4" (85mm) high.



*A complete parts kit for this transistor tester is being made available in conjunction with this article. For ordering information and prices, write to G.R. Whitehouse & Co., 10 Newbury Drive, Amherst, New Hampshire 03031.

By **Dave Cheney, WØMAY**, 4808 N. Monroe, Loveland, Colorado 80537

test. Of course, the most important aspect of these tests is to determine if the device is suitable for our needs. Admittedly the tests don't tell us anything about frequency response, but this requires an entirely different tester. If you really must know whether a device is germanium or silicon, an additional test can be made. Set a volt-ohmmeter or vacuum-tube voltmeter to the one-volt range, and connect the meter test probes between base and emitter with the device plugged into the tester. Select npn or pnp, depending on the device type, and set the function switch to the *B500* position. A germanium device will read 0.2 to 0.3 volt while a silicon will read 0.6 to 0.7 volt.

The short test is really an I_{ces} test, as shown in **fig. 1A.** In this test the full-scale meter reading is 5 mA. Resistor R1 limits the current to about 6 mA, depending on battery condition. This resistor provides some meter protection and limits battery current drain during short tests. A meter reading will be obtained if the device has a collector-to-base or a collector-to-emitter short. To see why an npn device will show a short when the toggle switch is set to pnp (or vice versa), visualize the collector-base junction as a reversed-biased diode in normal operation. If the battery polarity is reversed, the collector-base junction becomes forward biased, which is the case when the toggle switch is in the wrong position.

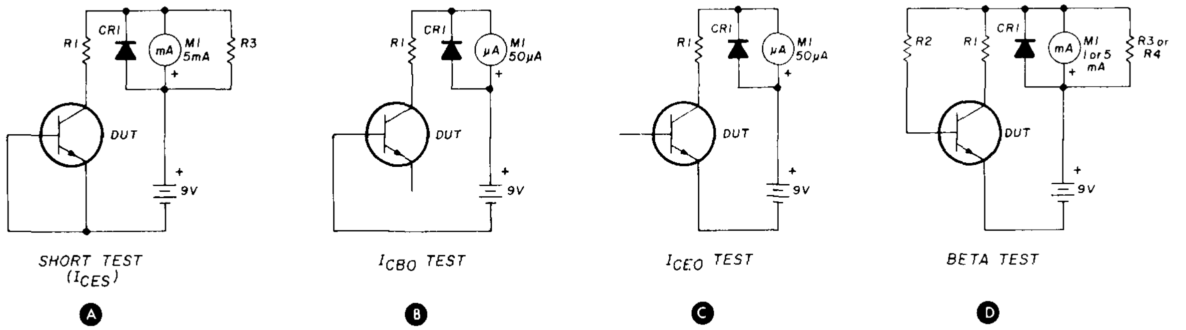


fig. 1. Circuits demonstrating the transistor tester operating principles. R1 is a current-limiting resistor and is in the circuit at all times. R2 sets the base current value for beta tests, and R3 is a meter shunt resistor, which is discussed in the text.

The I_{cbo} test circuit is shown in **fig. 1B**. The meter reads 50 μA full-scale, as no meter shunt is used. This value of current seems to be a good compromise for checking the collector-to-base leakage of most transistors. The same current range was used for the I_{ceo} test. Some transistors, especially germanium types with high I_{cbo} and beta, will pin the meter. Fortunately, this doesn't happen very often. If you desire a higher current range for this test and still wish to retain the meter calibration, a meter shunt resistor could be connected to set the full-scale value to 500 μA. The I_{ceo} test circuit is shown in **fig. 1C.**

The *B500* and *B100* test positions use the same circuit, except that different meter-shunt values are used. The *B500* test uses the same meter shunt used in the *short* test. On the *B100* test, a meter shunt resistor sets the full-scale current to 1 mA. The basic circuit is shown in **fig. 1D,** but only one shunt resistor is shown.

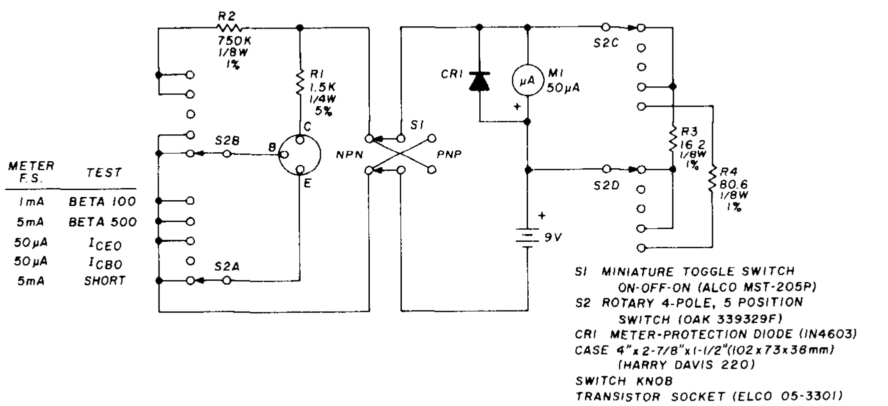


fig. 2. Transistor-tester schematic. Most of the parts are available from Allied Radio Shack stores.

The complete test circuit is shown in **fig. 2.** Note that collector resistor R1 is connected at all times. Its purpose has already been explained. Note, however, that this scheme does not adversely affect the test readings.

The diode across the meter is for over-current protection. Any small-signal germanium unit is suitable. The meter tracking accuracy doesn't compare with that of more costly units but is entirely satisfactory for this use.

The meter that maintains its zero position while in use has good damping. At the present price of about $7.95 it's a good choice for this kind of project. The meter isn't supplied with electrical data on either meter resistance or full-scale terminal voltage. Information such as this seems to be missing from many of Radio Shack's products. I suspect that the low price and lack of information means that the specifications aren't held to close tolerances.

The shunt resistors can't be calculated without having one or the other of the above specifications, so I measured mine. I applied current until the meter read full scale then measured the terminal voltage, which was 80 mV. (I didn't carry the test to its conclusion to see if the full-scale current was truly 50 μA.) Assuming the proper current value, an Ohms law calculation shows that my meter should have an armature resistance of 1600 ohms. If you're so inclined, you can measure your meter terminal voltage and recalculate the shunt resistor values for R3 and R4 using

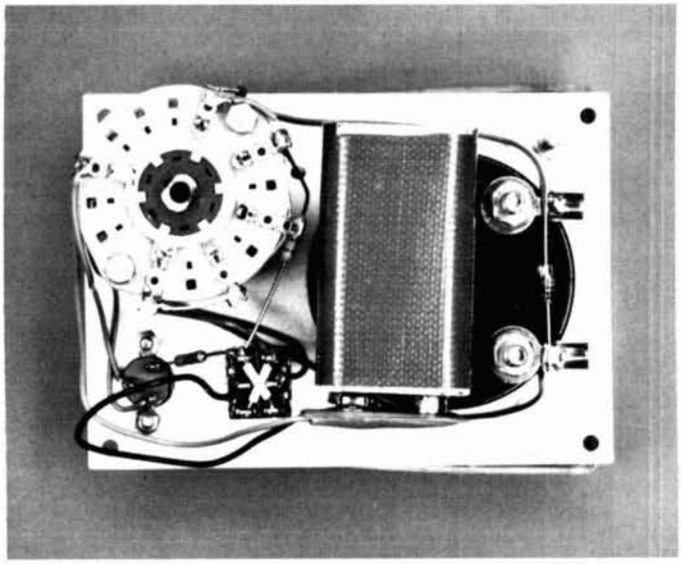
$$Rs = \frac{I_m}{I_s} \times R_m$$

where: R_s = *shunt resistance*
R_m = *meter resistance*
I_m = *meter current*
I_s = *shunt current*

Note that I_s = circuit current minus meter current (I_m).

construction notes

The transistor tester is very compact and the battery is a tight fit. My original intention was to use an 8.4 volt mercury battery (E-146X), which is almost the same size as the common carbon-zinc 9-volt transistor radio battery. The problem is that the two batteries are not exactly the same size. The mercury battery is just slightly thicker and will not allow the front panel to fully close. I mention this because the mercury battery is the most suitable for this application. The mercury battery has a relatively flat discharge characteristic, so that the terminal voltage remains fairly constant until the end of its life. Such a battery will improve the long-term accuracy of the tester. I didn't realize the physical differences between the two batteries until it was too late, and the carbon-zinc cell is used at present. The battery is positioned between the bottom of the case and the back of the meter. The rotary switch in my tester was a junk box item and it's not as suitable as the one in the parts list. The recommended switch uses only two wafers, which provide more room inside.



Transistor tester parts layout. A slightly larger case than used here (see fig. 3) may be used to accommodate a type E-146X 8.4-volt mercury battery, which will improve the long-term accuracy of the tester.

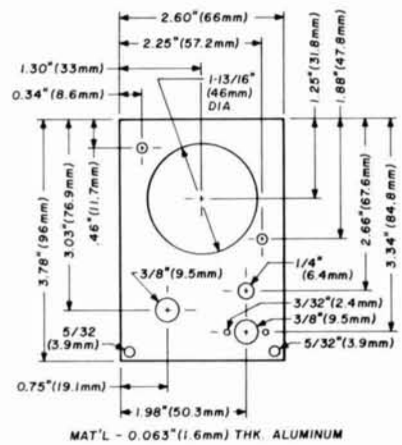


fig. 3. Front-panel layout viewed from the rear. The two 5/32-inch (3.9mm) holes at bottom are located 0.156 inch (3.9mm) in from each side and are for panel-to-case mounting screws.

Those who wish to use my layout may refer to **fig. 3** for the front panel dimensions. Note that this is the rear view of the panel, and that the meter-mounting screws are not symmetrically displaced from the center of the meter cutout.

alignment and test

No alignment is needed other than adjusting the meter mechanical zero. The battery should be replaced when its loaded terminal voltage reaches 7.5 V. If the voltage falls below that value, the *B500* test will read low. A simple battery check may be performed as follows:

1. Set the function switch to *short*.

2. Set the toggle switch to either position.

3. Insert a small bare wire in the test socket between the collector and emitter pins.

4. If the meter reads less than 50, replace the battery.

There you have it: a handy-dandy transistor tester you can take to the surplus store in your pocket. If you've read this far, you probably need one too.

ham radio

integrated circuit base-step generator

A straightforward circuit which may be used in building a curve tracer

Several articles have appeared recently describing curve tracer adapters for oscilloscopes. These adapters provide a means of measuring and displaying the current-versus-voltage characteristics of two- and three-terminal semiconductors on an oscilloscope. All of these adapters have two basic sections: a collector sweep circuit, and a base-step generator.

The collector sweep circuit generates a sweep voltage which is applied to the collector of the device under test. This voltage is usually derived from stepped-down line voltage which has been halfwave (60 Hz) or full-wave (120 Hz) rectified. The magnitude of the waveform is controlled by either an adjustable resistive divider or by a variable autotransformer. The circuit also usually contains a resistor for sensing collector current, and/or current-limiting load resistors. The design of this portion of the curve tracer adapter is straightforward and has been adequately discussed in previous articles.[1,2]

base-step generator

To generate a family of curves for three-terminal devices, the adapter must include a base-step generator in addition to the collector sweep circuit. This circuit generates a series of voltage or current steps which are synchronized with the beginning of each collector voltage sweep. These steps are then applied to the base or gate of the three-terminal device under test. The accuracy of this portion of the adaptor is a major factor in the overall accuracy of the curve tracer adapter.

To achieve good accuracy and low parts count, the base-step generator circuit of **fig. 1** was designed using a digital-to-analog, integrated circuit approach.

The resulting circuit has the following features:

1. Calibration of the circuit involves only one adjustment.
2. Accuracy of the circuit is determined only by the accuracy of resistor ratios, not absolute resistor values.
3. A true current source supplies base current.
4. The number of current or voltage steps is selectable.
5. Parts count is low and therefore construction is easy.
6. It is easily adapted to the builder's individual requirements.

circuit

The heart of the circuit is Motorola's MC1406L, a six-bit, digital-to-analog (D/A) converter. Before introduction of this device, most D/A converters were too expensive to be used by amateurs in their projects. Now, a D/A converter is available that is within most amateurs' budgets.* The basic configuration of the MC1406L is shown in **fig. 2.**

A reference current, I_{ref}, is established and flows into pin 12. I_{ref} is given by

$$I_{ref} = \frac{V_{ref}}{R_{12}}$$

The output current, I_o, which flows into pin 4, is an accurate fraction of I_{ref}. This fraction is determined by the digital word present at the inputs of the MC1406L, pins 5 through 10. The output current is given by:

$$I_o = I_{ref}\left(\frac{\overline{A}_1}{2} + \frac{\overline{A}_2}{4} + \frac{\overline{A}_3}{8} + \frac{\overline{A}_4}{16} + \frac{\overline{A}_5}{32} + \frac{\overline{A}_6}{64}\right)$$

For example, if the digital inputs (A_1 - A_6) are of the

*Single quantities of MC1406L are available at the price of approximately $5.90.

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form 101100, then $\overline{A_1}$ through A_6 would be 010011, and the output current, I_o, would be

$$I_o = I_{ref}(\frac{0}{2}+\frac{1}{4}+\frac{0}{8}+\frac{0}{16}+\frac{1}{32}+\frac{1}{64})$$

$$= I_{ref}(\frac{19}{64})$$

The output current can range from 0/64 to 63/64 of I_{ref} in increments as small as 1/64, depending on the state of the digital inputs. A set of guidelines is given in Appendix 1 on the proper operating conditions for the MC1406L IC.

If the output of a digital counter is connected to the inputs of the MC1406L, a series of current steps result on its output. This is the technique that is used in the base-step generator of **fig. 1**. Referring to the circuit, a train of clock pulses is derived from rectified line voltage. My curve tracer adapter used full-wave rectification of the line voltage for the collector sweep. Therefore, the ac voltage from which the clock pulses are derived is likewise full-wave rectified. This voltage is applied to Q1 at point A. The pulses from Q1 are inverted by U1A, and its output is applied to the clock inputs of U2 and U3. These J-K flip flops, along with U1B and U1C, form a synchronous divide-by-eight counter.

The outputs of this counter are then applied to the $A_1 - A_3$ inputs of the D/A converter, U5. I_{ref} is adjusted by potentiometer R1 to be 400 μA and the inputs A_4 through A_6 are tied to +5 volts. With this configuration, the output current into pin 4 is incremented 1/8 I_{ref} or 50 μA, each time the counter is incremented. Note that the minimum increment of current that can be obtained with this configuration is 1/8 I_{ref}, or 50 μA. If current increments other than 50 μA are desired, they can be obtained by appropriate adjustment of R1 and by using inputs A_2-A_4, A_3-A_5, etc. The guidelines for proper MC1406L operation, as set forth in Appendix 1, should always be followed when such a modification is done.

The output of U5 is then fed into a current amplifier composed of U6, Q2, and their associated resistors.

The basic configuration of the current amplifier is shown in **fig. 3**. The relationship between the input current I_1 and the output current I_2 is given by

$$I_2 = I_1 \ (1+\frac{R1}{R2})$$

An important feature of this configuration is that the output current is constant if the input current is constant, independent of the voltage between the output terminals. Note that the accuracy of the current gain is dependent only upon the ratio of R1 and R2, not on their absolute values. This affords the builder the opportunity of obtaining highly accurate current gains without the use of expensive precision resistors.

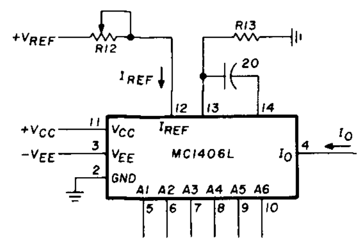

fig. 2. The output current flowing into pin 4 of the MC1406L is an accurate fraction of the reference current flowing into pin 12. The fractional portion of I_{ref} appearing at I_o is determined by the digital word present on inputs A1-A6.

This current amplifier configuration is used in the circuit of **fig. 1**. Transistor Q2 reduces the amount of current U6 must supply by a factor of Q2's beta. Resistor R9 converts the current steps into voltage steps for fet measurements. This resistor is the only precision part necessary in the circuit. U4 and S1 select the number of steps generated by resetting the counter section at the appropriate point in the count sequence. The circuit power supply is shown in **fig. 4**. At this point two words of caution are in order:

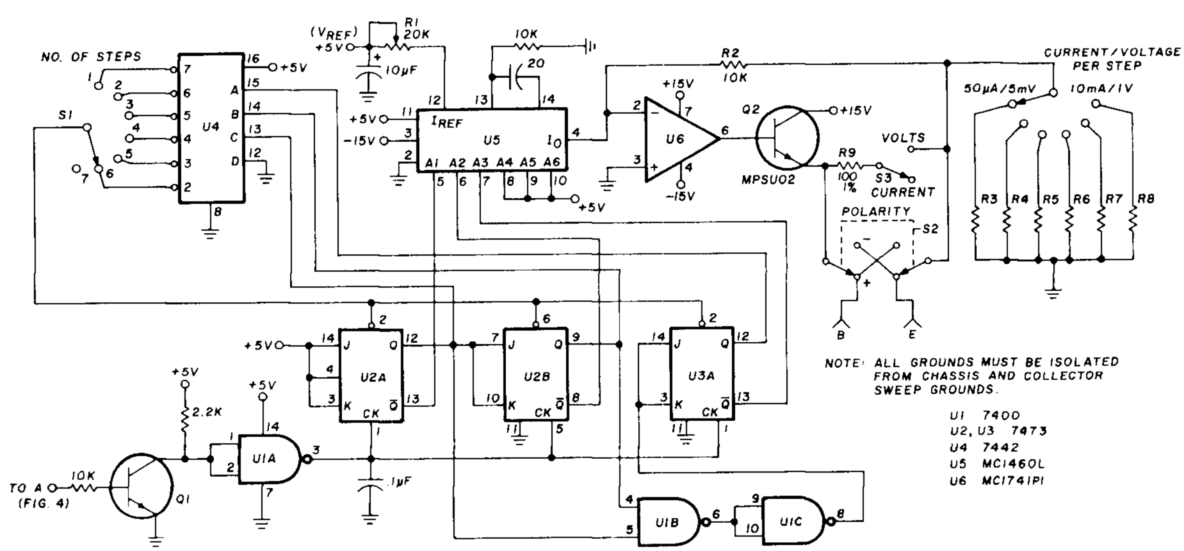

fig. 1. The base-step generator using the MC1406L six-bit, digital-to-analog converter. The values for resistors R2 through R8 are listed in table 1. R1 is a 10-turn 20k potentiometer. Q1 is a general-purpose npn with dc current gain of about 30.

1. Be extremely careful *not* to apply voltage steps to the base of bipolar transistors, or excessive base current will result.

2. The ground for the step generator circuit *must* be isolated from the collector sweep circuit and chassis grounds for proper operation.

construction

Normal construction practices are applicable. However, it is important that the power supply leads be properly bypassed. For the digital portions, a 0.01 µF disc capacitor for every five IC packages is satisfactory. All linear device supply voltages should be bypassed as close to the device as is possible with 0.1 µF disc capacitors.

table 1. Values for R3 through R8 are shown in last column as a ratio of R2 for various gains and voltage- and current-step ratios.

current step	voltage step	gain	R
50 µA	5 mV	1	∞
100 µA	10 mV	2	R2
500 µA	50 mV	10	R2/9
1 mA	100 mV	20	R2/19
5 mA	500 mV	100	R2/99
10 mA	1000 mV	200	R2/199

With the exception of the current amplifier's gain determining resistors, circuit components are noncritical and appropriate substitutions can be made. The accuracy of the circuit is directly dependent upon the selection of resistors R2 through R9.

As was previously mentioned, the gain of the current amplifier is determined by the ratio of two resistors. If an accurate digital ohmmeter or resistance bridge is available, it is a simple matter to "bridge" the resistors necessary to obtain the desired gain. For example, if it is desired to obtain a gain of 100, then R2/R = 99. Since R2 equals approximately 10k, R should be approximately 110 ohms. R2 would be accurately measured and its value noted. Then resistors of 100 ohm nominal value would be measured and a resistor selected whose measured value is closest to being 1/99 of R2's measured value. Highly accurate resistor ratios, and therefore gains, can be obtained in this manner.

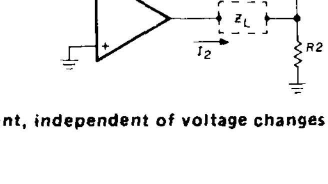

fig. 3. Current amplifier used to buffer the output of the base-step generator follows the configuration shown here. If input current is constant, then output current will also be constant, independent of voltage changes across Z_L.

Of course, this method can not be used if a digital ohmmeter or resistance bridge is not available, or if you don't have a healthy stock of resistors on hand. In this case, precision (1%) resistors must be obtained and used in combinations to obtain the appropriate resistor values.

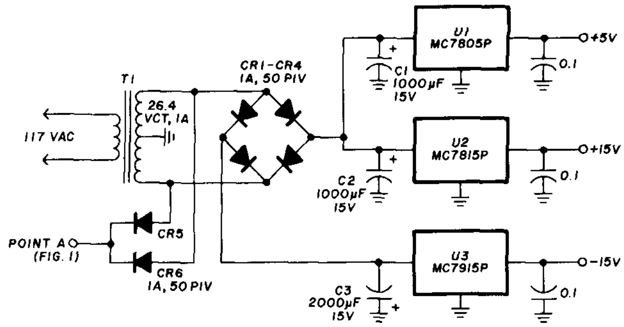

fig. 4. A suitable power supply for the base step generator of fig. 1.

To calibrate the circuit, set switch S1 to step position 7, switch S3 to the VOLTS position, and switch S4 to a midrange position. Connect an oscilloscope to the B and E output terminals and adjust R1 to obtain the correct voltage steps. The circuit is now ready for use.

conclusion

This circuit offers versatility and adaptability. In addition, its accuracy is limited only by the accuracy of the instruments that are used to select the components and to calibrate the circuit. The inclusion of this base-step generator circuit in a curve tracer adapter provides a highly accurate and extremely useful accessory for an oscilloscope.

appendix

The following are some guidelines for proper circuit operation of the MC1406L six-bit, digital-to-analog converter. They are by no means maximum limits, nor are they intended to define all the possible regions of operation. Instead, they are given as an aid for individual design and are appropriate for most circuit configurations. For more detailed information on the MC1406L's capabilities and applications, see the manufacturer's data sheet.

1. Normal operating voltages:

$$V_{CC} = +5 \text{ volts}, V_{EE} = -15 \text{ volts}$$

2. I_{ref} should be equal to 500 µA to 4 mA

3. V_{ref} should be equal or less than +5 volts and well regulated.

4. If V_{ref} is obtained from a logic supply, it should be heavily bypassed close to R12 (fig. 2).

5. R13 should be approximately equal to R12.

6. Voltage on pin 4 (output pin) should never exceed plus or minus 0.4 volt. This may be accomplished by the use of op amp buffering.

references

1. Albert Klappenberger, K3KWX, "An Accurate Solid-State Component Curve Tracer," *CQ,* July, 1974, page 20.
2. Daniel Wright, WA9LCX, "Transistor Curve Tracer," *ham radio,* July, 1973, page 52.

ham radio

readout display

for two-meter digital synthesizers

Dress up your transceiver with a 7-segment display for easy-to-read switch settings

The readout display described here is a great convenience when setting up the channel switches on your two-meter transceiver in the dark or while operating mobile. The display shows the decoded BCD count that controls the synthesizer. If the BCD input to your synthesizer is through front-panel switches, the display makes a nice remote switch-position indicator.

My setup consists of a Heathkit HW-202 and a GLB synthesizer built from a kit. The display is intended for use with the GLB; however, it will work with all the homebrew synthesizers I've seen, of which there are many in this area. I built a three-digit display for $13.00; a two-digit display would be about $8.00. The three-digit display covers all six switches, while a two-digit display would cover the 100- and 10-kHz positions. Since the decoded BCD count that's loaded into the synthesizer is taken from the switches, no mods are required to the synthesizer.

description

The front-panel switches used for frequency selection on the GLB are ten-position rotary switches; i.e., each switch has ten positions with binary-decimal-coded outputs that represent the decimal numbers 0-9. Six identical switches are used; three represent the received frequency (RX), and three represent the transmit frequency (TX). The switches are marked 0 through 9.

The three numbers in a three-digit format represent respectively MHz, 100 kHz, and 10 kHz. Thus if the RX switches are set to 694, for example, and the TX switches are set to 634, you'd be receiving on 146.94 MHz and transmitting on 146.34 MHz. A two-digit format would display the 94 only, for 146.94 MHz. Most homebrew synthesizers have ten-position thumbwheel switches (BCD) that are mechanically different but electrically the same as in the GLB synthesizer.

Since the RX/TX count is loaded into the synthesizer at the same point, the display will normally read out the numbers set up on the RX-selected switches. When you activate the PTT line the readout will automatically display the numbers from the TX-selected switches; this allows three digits to read out all six switches, displaying only those in use.

construction

Fig. 1 is the basic circuit and can be used for all three digits. The transistors aren't critical; most any type of npn device will work. The diodes should be silicon switching types. Substitutes for the readouts are MAN-4 or DL-4. *You'll need two identical circuits as in **fig. 1**,* each of which will be used for the 100-kHz and 10 kHz readouts. The 7404 IC module has six separate inverters. If you build a three-digit display, sections 5 and 6 from the 100- and 10-kHz 7404 modules provide the four inverter for the MHz readout, using pins 10, 11, 12, and 13.

On some synthesizer models the MHz switch is locked from going below 4 and above 7. If you have this type,

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build the MHz display as shown in **fig. 2** using the two unused inverters from the 100-kHz 7404. For the 5 volt supply I used a LM309K regulator (**fig. 3**). Component layout isn't critical. I mounted everything on perfboard except the diodes, which I mounted inside the synthesizer. If you plan to have your display located remotely

10-kHz switch. The point where the diodes connect to each other is the point to make your voltage measurements and to connect the readout diodes.

To find the BCD value of each diode, connect the minus lead of a voltmeter to chassis, turn power on, set both 10-kHz switches to number 1. With the positive

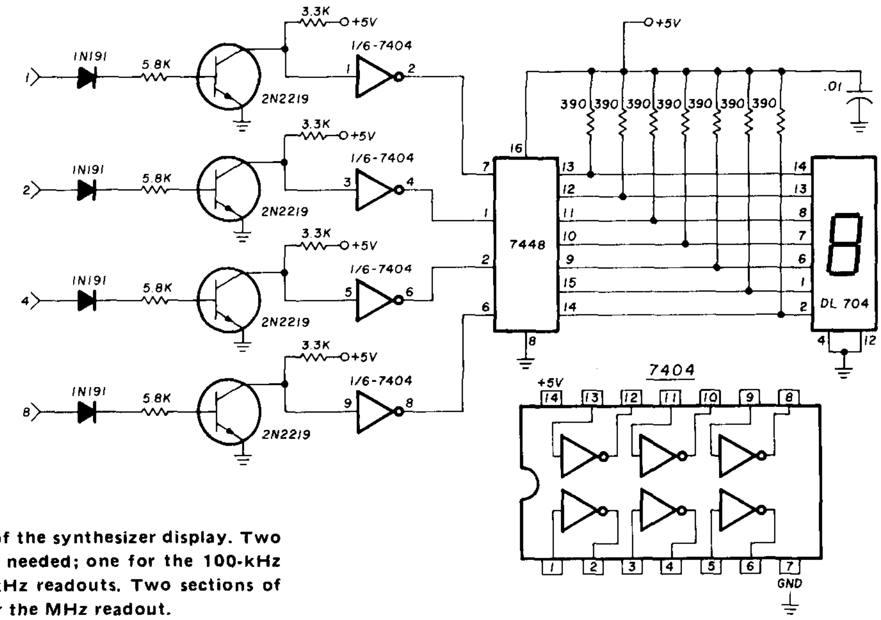


fig. 1. Basic circuit of the synthesizer display. Two identical circuits are needed; one for the 100-kHz and one for the 10-kHz readouts. Two sections of the 7404 are used for the MHz readout.

from the synthesizer, such as dash mounted, small coax should be used for interconnecting wires and you still may have an erratic display while transmitting (this problem is discussed under troubleshooting).

I built my readout into a Minibox, bolted it to the top of the synthesizer, drilled a hole through both, and

lead measure the four diode connections. One and only one connection will be above +3 volts; this point is BCD 1. Move the 10-kHz switches to position 2 and measure again; also do this with the switches in positions 4 and 8. Now that you've determined the 1-2-4-8 diode positions, solder the respective diodes from the display to these

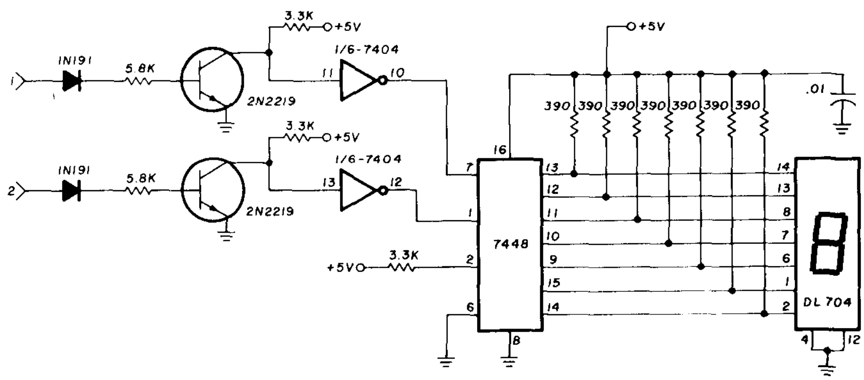


fig. 2. Circuit for limited-range MHz switch. Connect the 2-display diode to the point that measures +4V for both 6 and 7 positions (see text for measurement). The 1-display diode is connected to the other MHz-diode point.

used standard hookup wire. I cut out the front of the Minibox just enough to view the LEDs, then put a polaroid filter over the cutout.

No modification to your synthesizer should be required to connect the display. However, you must connect the readouts to the proper point for a 1-2-4-8 BCD decoding with automatic switching (see **fig. 4**). Remove the cover from the synthesizer. At the back of the 10-kHz switch you'll see four diodes connected to it, and they in turn connect to four diodes from the lower

points (watch the polarity). Repeat this operation for the 100 kHz and the MHz readouts. If you have only two diodes on the MHz switch, see **fig. 2**.

test and troubleshooting

When all connections have been made, position the RX switch to use the lower set of switches and turn power on. The display should represent the output from the lower switches. Move the RX switch to the upper switches and the display should change to represent the upper switches. With the RX switch on the upper set of switches and the TX on the lower set, ground the PTT line and the display should change from upper to lower switches.

If a readout is in error from a switch setting and the rig is on the right frequency, then you have made a wiring error, most likely at the diode 1-2-4-8 connections, or you have used a bad component. If the readout

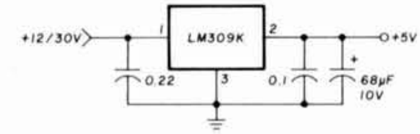
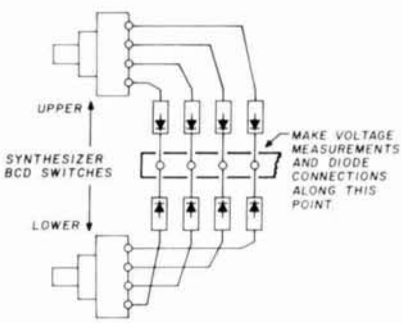


fig. 3. Regulator circuit for obtaining +5 volts. Pin 3 is case ground. The 68-μF capacitor can be any value between 10 to 100 μF at 10 volts.

is correct or erratic and the rig is on the wrong frequency, check for a diode connected backward or a shorted diode. If the reading is correct in RX but in error in TX, you have rf leakage from your rig. Check the reading with the rig terminated into a good dummy load. The diodes isolate the readout from the synthesizer, the transistors bring the signal to a TTL level, the 7404 inverts the signal to the correct polarity, and the 7448 decodes the signal to drive the DL704.

If trouble still persists, such as an erratic readout on transmit, check for rf leakage in and around your set. The shields of all leads from the synthesizer to the transceiver should be grounded at the point of entry into the transceiver. Check for poor antenna connections, high vswr, loose hardware in both rigs, a poor microphone connection, or an oscillating power supply. The readout should be correct and steady, even with a 50-watt amplifier sitting on top of it.

fig. 4. Upper and lower 10-kHz synthesizer BCD switches showing how to connect readout circuit for proper BCD decoding.



The reason for two types of MHz switch hookups is that the GLB has a MHz switch that will not go below 4 (144.00 MHz) or above 7 (147.99 MHz). This prevents out-of-band operation. However, some amateurs wish to use their synthesizer on MARS frequency so they order a band-extended version, which allows the MHz switch to go from zero to 9 (144 to 149 MHz). All homebrew rigs (to my knowledge) will go from 140.00 to 149.99 MHz, or at least the switch is not locked out to prevent it.

ham radio

vhf/uhf techniques

Joe Reisert, W1JAA

matching techniques for vhf/uhf antennas

In my last column, in the May issue[1], I discussed feed systems, feedlines, baluns, matching networks and matching techniques. This month I will concentrate not only on matching techniques but also on easily-built test equipment which can be used to assist in matching and evaluating antenna performance.

More often than not, the station transmitter is used as a signal source to check vhf and uhf antenna performance. This is easy to understand since most stations are equipped with an in-line vswr indicator. However, using the station transmitter for antenna evaluation has several drawbacks. The most obvious problem is that adjustments cannot be readily made with power applied. Another problem which has only recently been mentioned is the possible hazard due to exposure to high-intensity rf fields.[2]

A better technique for measuring and matching vhf and uhf antennas uses a low-power (1 to 100 mW) amplitude-modulated (usually 1-kHz square wave) signal generator. This generator can be either a standard commercial signal generator (such as the Hewlett-Packard 608) or a small solid-state signal source such as that described later in this column. Low power testing eliminates most of the problems associated with using the station transmitter. It is also much less time consuming because adjustments can be made with rf power applied. Furthermore, construction of such an rf generator is simple and straightforward.

Most in-line vswr meters (such as the *Monimatch*) use a microammeter or milliammeter as an indicator. This requires moderate power (more than 1 watt) to drive the meter. Dc amplifiers can be used to increase sensitivity, but they tend to drift and can be quite complex. If a modulated rf source is used, the detected rf signal is ac (rather than dc) so it can be easily amplified to a suitable level to drive a vswr indicator. A typical test set-up is shown in **fig. 1**.

A suitable low-power 144-MHz (10-milliwatt) signal source for antenna measurements is shown in **fig. 2**. It consists of a 72-MHz crystal oscillator followed by a times-2 multiplier. This design follows the general guidelines of reference 3. Experimental tests have shown that *overtone crystal oscillators can be balky starters.* Therefore, I recommend that the oscillator be run continuously while keying the doubler. Simple, off-on (square-wave) keying is preferred. *I have also used this technique* on a 432-MHz signal source which uses a 108-MHz oscillator followed by two-keyed doublers. Over five years of rough treatment have not caused any problems.

There are several requirements for a suitable rf source. Output power should be constant. This can best be controlled by using a regulated power supply. Battery operation is recommended for field use, but the batteries should be checked periodically for signs of discharge. For best performance in the field, a simple 3-terminal, 12-volt, IC voltage regulator following a 16- to 20-volt battery supply is recommended.

Another rf generator requirement is freedom from load variations (such as the antenna, etc.). This can be satisfied by a 3 to 6 dB attenuator between the generator output and the load. All spurious or harmonic outputs should be at least 30 to 40 dB below the output signal. A double-tuned output filter is usually sufficient (see **fig. 2**). Finally, a shielded box around the generator prevents excessive radiation or signal pickup.

Construction is straightforward. My units are built on a 2- by 4-inch (5x10cm) piece of double-sided epoxy fiberglass PC board which is attached to the inside of the top lid of a Pomona 2901 shielded box. All grounded components are soldered to the copper ground plane. Be sure to remove the paint and protective coating where the box and lid make contact. This insures a well-shielded generator – a must for good measurement.

The 144-MHz rf generator has a CW output of 10 milliwatts and a modulated output of 5 milliwatts. All spurious and harmonic frequencies are 35 to 40 dB below the output. These characteristics are near optimum for the low-power antenna tests to be described in this article.

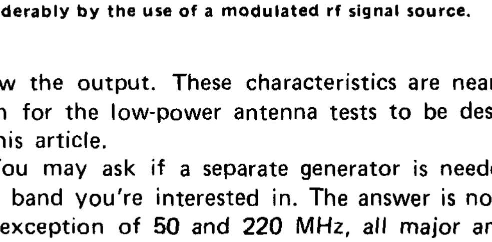


fig. 1. Low-power vswr test set-up. System sensitivity is increased considerably by the use of a modulated rf signal source.

You may ask if a separate generator is needed for each band you're interested in. The answer is no. With the exception of 50 and 220 MHz, all major amateur vhf/uhf bands are harmonically related to 144 MHz so it's only necessary to build a 144-MHz generator and add on amplifiers and multipliers for other bands. Keying the multipliers is not necessary because the 144-MHz source will supply sufficient modulation. Such a scheme is shown in **fig. 3**. It will be left to the user to provide the circuitry necessary to implement this system.

For several years I have been using a simple multivibrator and series pass transistor as the modulator for my rf generators. At the insistance of K1LOG, I finally updated my circuit to use an NE555 IC. One NE555 timer replaces the multivibrator and its 15 plus components and is easily adjustable from 750 to 1500 Hz. A series pass transistor, while not absolutely necessary, was added since it increased the output by about 2 dB. A complete schematic of the modulator is shown in **fig. 4**.

This unit is built in a small chassis box with two or more 3- or 4-pin Jones connectors on the output. The output connectors provide ground, +12 volts and keyed 12 volts, thus allowing quick changes or additional units to be plugged in (see **fig. 3**).

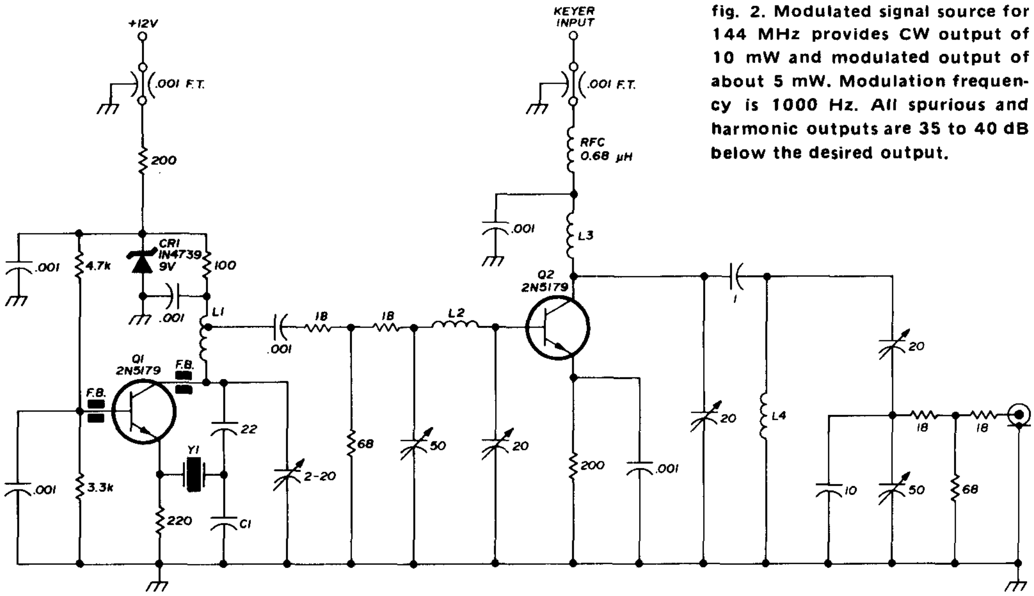


fig. 2. Modulated signal source for 144 MHz provides CW output of 10 mW and modulated output of about 5 mW. Modulation frequency is 1000 Hz. All spurious and harmonic outputs are 35 to 40 dB below the desired output.

C1	as large as possible, consistent with good oscillator starting (100 pF typical)
FB	ferrite bead
L1	9 turns no. 24 (0.5mm) on Amidon T-37-12 toroid core; tapped 3 turns from cold end
L2	15 turns no. 28 (0.3mm) on Amidon T-25-12 toroid core
L3,L4	4 turns no. 24 (0.5mm), 1/4" (6.5mm) inside diameter, 1/4" (6.5mm) long
Y1	72-MHz, 5th-overtone, series-mode crystal

vswr measuring gear

In the May column I mentioned some recommended vswr measuring gear. In this column, I will describe simple homemade equipment that can be used instead of slotted lines, network analyzers and reflectometers. The vswr bridge is a very versatile unit since it can be used to measure various impedances, depending on the reference. Suitable bridges are commercially available from a number of firms including Texscan, Anzac, Telonic and Wiltron. Sometimes these units can be found on the surplus market.

A vswr bridge can be built to work through several GHz, but this requires careful attention to size components, and layout. However, with some care a simple homebrew bridge can be made to work well through 450 MHz. Such a unit is shown in **fig. 5**. Operation of this bridge is easily understood. If identical loads are placed at J2 and J3, the signals at opposite ends of R3 are equal and in phase, and there will be no output at J4. However, if the impedance of the unit under test at J3 is different from that of the reference load, an output proportional to this difference will be present at J4. The reference load and unit under test can be any convenient impedance value from 25 to 100 ohms. However, the bridge circuit in **fig. 4** is designed for optimum performance at 50 ohms.

The values of R1 and R2 are not critical, but both should be the same type and well-matched for best accuracy. This can be easily accomplished by comparing 6 to 10 similar resistors on an ohmmeter and choosing

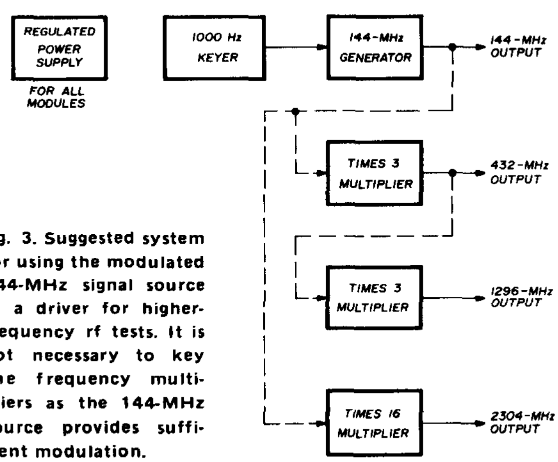


fig. 3. Suggested system for using the modulated 144-MHz signal source as a driver for higher-frequency rf tests. It is not necessary to key the frequency multipliers as the 144-MHz source provides sufficient modulation.

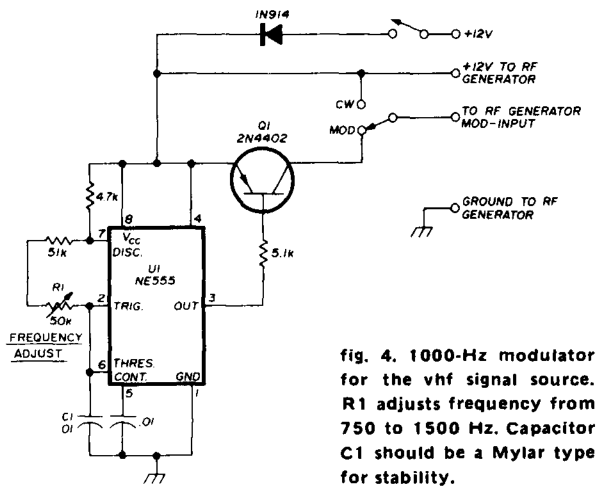
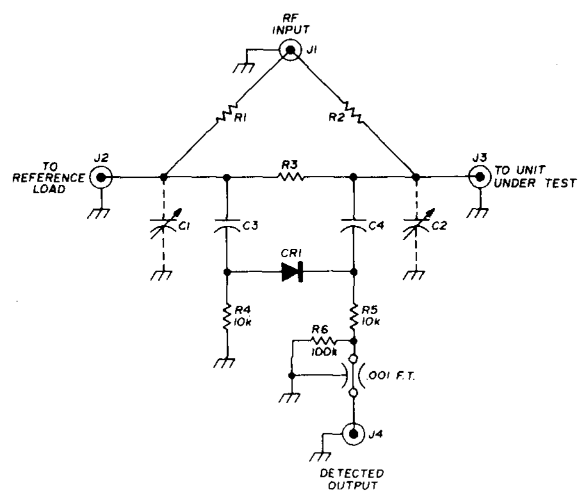


fig. 4. 1000-Hz modulator for the vhf signal source. R1 adjusts frequency from 750 to 1500 Hz. Capacitor C1 should be a Mylar type for stability.

the two which are closest in value. R3 can be one of the rejects since its value is not critical. I would suggest the use of 51-ohm, ¼-watt, carbon-composition resistors. If the bridge is primarily for use at 70 or 75 ohms, R1, R2, and R3 should be changed accordingly for best match to the device under test, but this is a fine point. Capacitors C1 and C2 are small copper tabs that can be added close to J2 and J3 if the ultimate in balance is desired (more about this later).

When building such a bridge, short leads and symmetry are the prime considerations because any long leads or stray capacitance will cause imbalance. A recommended layout is shown in **fig. 6**. I use a Pomona 2417 shielded box for the enclosure. It is a good choice for the components and type-N connectors.

To test the bridge a modulated rf signal is connected to J1 and an audio detector (described later) is connected to J4. Two identical loads are placed on J2 and J3. The detector output should be extremely low. If not, C1 or C2 can be added to balance out any residual signal. Removing either the load or reference will cause the detected output to rise from 20 to 40 dB or more, indicating proper performance. If two identical loads are swapped from J2 to J3 and vice versa, the detected output should not change.



C1, C2	small capactive tab required for balance (see text)
C3, C4	0.001 µF (small disc ceramic or chip capacitor)
CR1	1N82A or equivalent germanium diode
J1, J4	UG-290A/U BNC connector
J2, J3	UG-58/U type-N connector
R1, R2	47 to 55 ohms, matched (see text)
R3	51 ohms, ¼-watt carbon composition
R4, R5	10k ohms, ¼-watt carbon composition
R6	100k ohms, ¼-watt carbon composition

fig. 5. Homebrew vswr bridge which is suitable for use through 450 MHz. When building the bridge short leads and symmetry are important considerations because of imbalance which can be caused by poor layout. A typical layout is shown in fig. 6.

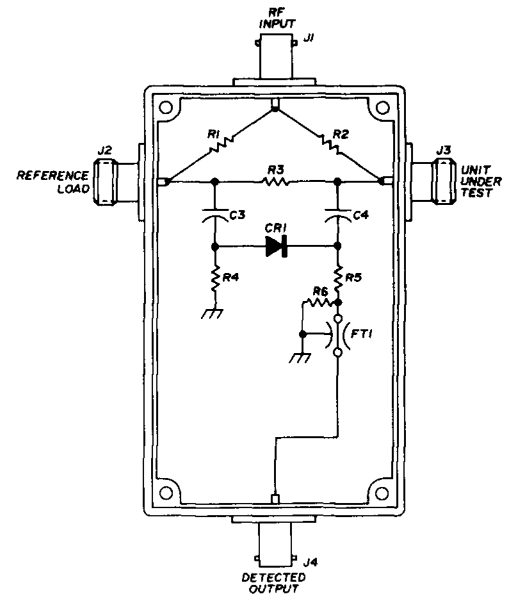


fig. 6. Recommended parts layout for the vswr bridge shown in fig. 5. Enclosure is a Pomona 2417 shielded box. Connectors J2 and J3 are type-N; J1 and J4 are BNC.

Hybrid couplers are also a good choice for vswr measurements and are preferred for operation above 500 MHz where bridges are less accurate. Hybrids are also quite suitable for lower frequencies. Usually quite expensive, recently a low-cost, broad-band, 500 kHz to 400 MHz hybrid coupler became available from Anzac Electronics.* It is mounted in a half-size relay can and is easily adaptable to microstrip circuitry. A schematic and microstrip circuit-board layout for the Anzac hybrid coupler is shown in **fig. 7**.

If all inputs and outputs of the hybrid coupler are properly terminated, and an rf signal is present at *input 1*, the same signal will be present at *output 1* (less the coupling power) and no signal will be present at *output 2*. The signal level at *input 2* will be below the level at *input 1* by the coupling factor (19.5 dB in this case). However, if the vswr at *output 1* is not 1:1, a signal will

*Anzac model CH137 available from Anzac Electronics, 39 Green Street, Waltham, Massachusetts 02154. Price is $13.00 plus tax and shipping.

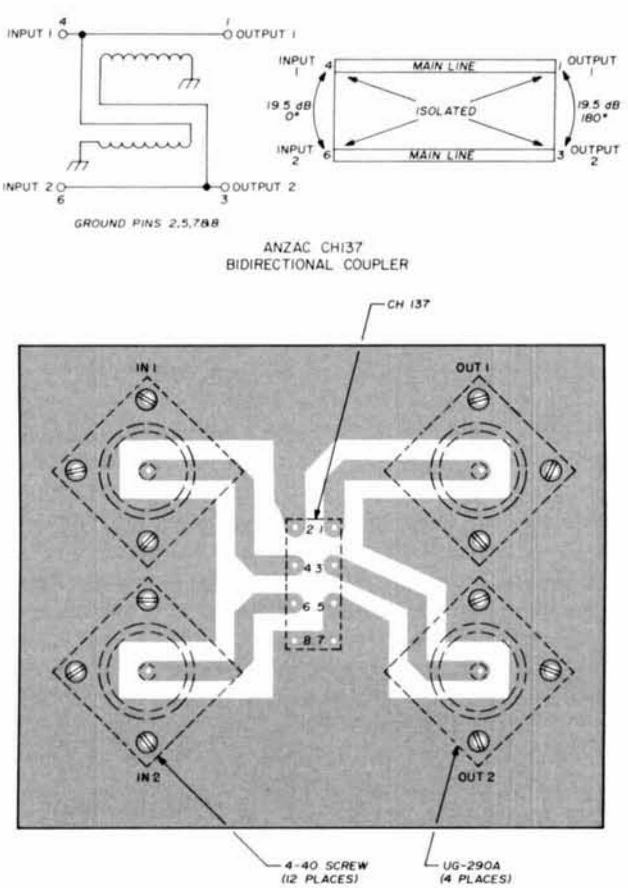


fig. 7. Broadband 19.5 dB directional coupler for use through 500 MHz uses commercially available module (Anzac CH137) and printed-circuit board. The microstrip transmission lines on the 1/16" (1.5mm) double-sided G10 circuit board are 0.1' (2.5mm) wide [clear copper away at least 0.1" (2.5mm) from the microstrip lines]. All connectors are UG-290A/U BNC types; for best performance the shoulder on the rear of the connectors should be removed with a small lathe. Before installing components, on the top side of the board remove copper around pins 1, 3, 4, and 6 of the CH137, as well as around the center conductor of the four connectors.

be present at *output 2* which is proportional to the vswr at *output 1*. The level at *input 2* remains essentially the same.

To perform a vswr test, the signal generator is connected to *input 1; output 1* and *output 2* are terminated in good, nonreactive 50-ohm loads. A 50-ohm detector is connected to *input 2* and the level on the detector indicator is noted for reference. The 50-ohm load at *output 2* is now interchanged with the detector on *input 1* and the detected output should drop considerably (at least 20 dB). Next the load on *output 1* is removed and the device under test is connected. All that is necessary to complete a match is to adjust for minimum detected signal at *output 2*.

This coupler works well through 250 MHz. At 432 MHz there is some imbalance so if it is used at 432 MHz is is necessary to interchange the inputs and outputs, respectively (they are symmetrical, so operation should be identical), to determine which combination gives the best null when properly terminated. In my case *input 2* and *output 2* are better at 144 and 432 MHz.

A narrower-bandwidth stripline coupler with a bandwidth of 10% is shown in **fig. 8**. I have used this type of coupler through 2304 MHz with excellent results. Operation is identical to that of the Anzac unit. When building the stripline coupler be sure to keep any air gaps between the printed circuit boards to a minimum. Placing 1/8 inch (3mm) thick aluminum plates on top and bottom and bolting them together will keep the air gap to a minimum.

loads

Suitable 50- and 70- to 75-ohm loads are commercially available from a number of sources and can sometimes be found on the surplus market. A suitable homebrew load is shown in **fig. 9**. I have found that ordinary ¼-watt, carbon-composition resistors to be the least reactive and therefore the most suitable for this application. Half-watt and especially 1-watt units are definitely inferior in this respect. A symmetrical four-resistor load (as shown in **fig. 9**) has been the best performer – tests have shown this arrangement to work well through 2304 MHz. If a 75-ohm load is desired, the individual resistor values can be changed to 300 ohms.

It is often desirable to have known mismatches to aid in determining the true antenna vswr. A 75-ohm load makes an excellent 1.5:1 vswr reference on a 50 ohm system. Four 100-ohm resistors will make a good 25-ohm load which can be used for 2:1 vswr tests at 50 ohms. In all cases the coaxial connector chosen should be of suitable quality (type-UHF connectors are not recommended above 30 MHz).

Infinite vswr can be tested with a short circuit. Open circuits are not recommended since fringing capacitance will alter the results. A suitable infinite vswr load is also shown in **fig. 9**.

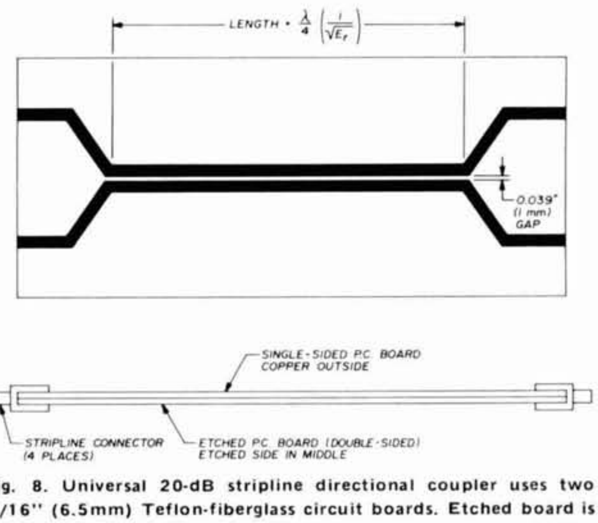


fig. 8. Universal 20-dB stripline directional coupler uses two 1/16" (6.5mm) Teflon-fiberglass circuit boards. Etched board is double copper clad; cover board is single copper clad. The quarter-wavelength of line is shortened by the dielectric constant of the circuit board as shown in the formula (2.5 for Teflon-fiberglass circuit board). Correct length is 4.3" (10.9cm) for 432 MHz, 1.43" (36.5mm) for 1296 MHz, and 1.28" (32.5mm) for 2304 MHz. Bandwidth is about 10%.

detector

A detector is built into the vswr bridge. If a hybrid coupler is used, you must build or purchase your own detector. It should be sensitive and well matched. Point-contact or zero-bias Schottky diodes are preferred because normal Schottky diodes are insensitive at low signal levels unless forward bias is applied. Since the cost of zero-bias Schottky diodes is presently quite high ($25 or more), low-cost point-contact diodes are preferred.

A schematic for a suitable detector using point-contact diodes is shown in **fig. 10**. The input is a 50-ohm termination and should be similar to the loads in **fig. 9**. It provides a dc return for the diode as well as providing a load for the hybrid coupler. Typical output is only 50 microvolts at -40 dBm, 5 millivolts at -20 dBm and 30 millivolts at zero dBm. The output is square law (output voltage doubles each time the input doubles) below -20 dBm and linear above -10 dBm. An amplifier is required at low levels.

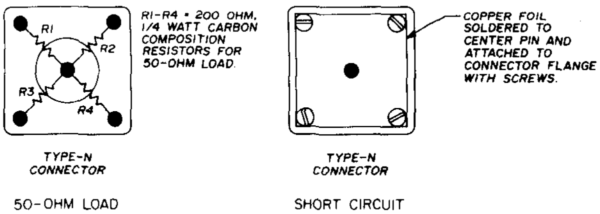


fig. 9. Simple homemade 50-ohm load and short-circuit for use through 2304 MHz. If 75-ohm termination is required, four 300-ohm, ¼-watt, resistors may be substituted.

The detector should have short leads on R1, CR1 and C1. I built mine in a Pomona 2417 box with the input connector on one end, a shield diagonally across the box for the ground return of the feedthrough capacitor, C1, and the output connector on the opposite end. This type of detector is suitable for use to 1000 MHz or so and can be used in many other applications.

vswr indicator

The output of an rf detector is very low at small signal levels. Therefore, an amplifier is needed to drive an indicator such as a meter, and it should be tuned to 1 kHz to work best with modulated signal sources.

Recently many Hewlett-Packard 415 type square law meters have become available on the surplus market at reasonable prices ($25 to $40). This is an excellent meter to use since it has high gain and is calibrated to match typical detectors. It also has many other uses. A suitable homebrew model has also been described in *ham radio*.[4]

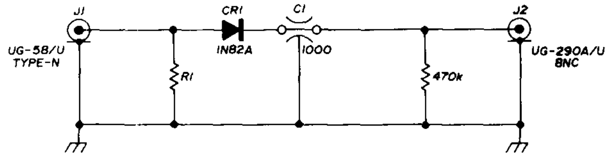


fig. 10. Simple rf detector for 50-ohm systems uses a germanium point-contact diode Upper frequency range is greater than 2304 MHz. Resistor R1 consists of four parallel-connected, 200-ohm, ¼-watt resistors (see fig. 9).

Recently I designed and built a simple, uncalibrated vswr meter that is easily transported and uses a minimum number of components. The circuit, which is shown in **fig. 11**, consists of a high-gain amplifier, a narrow-bandwidth (100 Hz) selective amplifier tuned to 1000 Hz, and a variable-gain output amplifier which drives a low-cost VU meter. This instrument is ideal for nulling-type vswr measurements, and uses only a single supply voltage. At 9 to 12 volts (not critical) the circuit draws only 5 to 6 mA so an inexpensive 9-volt transistor battery can be used.

matching techniques

Before making any vswr measurements, it pays to set up your vhf or uhf antenna in a clear area, on a tower, or on a wooden ladder pointing toward the sky. The length of the driven element should be set approximately as follows:

$$L = \frac{5500}{f} \quad (inches) \tag{1}$$

$$L = \frac{13970}{f} \quad (cm) \tag{2}$$

where L is the driven element length and f is the frequency in MHz. If the driven element passes through a metal boom it should be lengthened by adding approximately 75% of the boom diameter to compensate for the shortening effect. The length of the driven element is

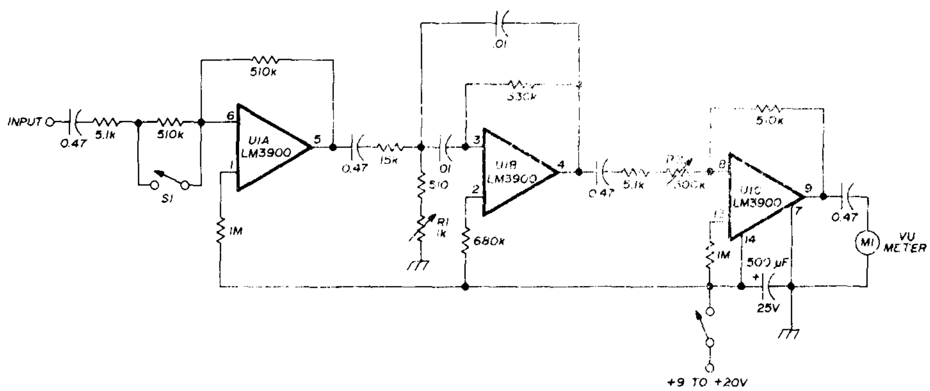


fig. 11. 1000-Hz selective amplifier and vswr indicator. Switch S1, when closed, increases gain approximately 100 times for low-level readings. Potentiometer R1 sets U1B to 1000 Hz, while R2 is used to set the reference on M1, a low-cost VU meter. The 0.01 capacitors should be Mylar types.

not critical for gain purposes and should be tuned for best vswr in conjunction with the matching system.

I have received several inquiries regarding the actual length of a free-space wavelength at vhf and uhf. At the present time authorities are in general agreement that light (and hence radio waves) travels at the rate of 299,792,456 meters per second. Therefore, the correct vhf and uhf formulas for wavelength are as follows:

$$\lambda = \frac{11803}{f} \quad (inches) \tag{3}$$

$$\lambda = \frac{29980}{f} \quad (cm) \tag{4}$$

where f is in MHz. These formulas should clear up any questions on the subject.

table 1. Return loss, dB, vs voltage standing-wave ratio.

return loss	vswr	return loss	vswr
40 dB	1.02	8 dB	2.32
35 dB	1.04	6 dB	3.01
30 dB	1.07	4 dB	4.42
25 dB	1.12	3 dB	5.85
20 dB	1.22	2 dB	8.72
15 dB	1.43	1 dB	17.39
10 dB	1.93	0 dB	∞

Now let's assume we want to match an antenna. If the feed system is similar to the ones mentioned in the last column (delta match, gamma match, etc.), it is only necessary to set up the low-power test setup shown in **fig. 1** using an appropriate vswr bridge or hybrid coupler. Initially, a 50-ohm load (or appropriate impedance) can be used to test the matching gear for a null. Then the antenna under test can be substituted and adjusted for minimum vswr. If a complete *null cannot be obtained*, a mismatch reference can be substituted to determine the actual vswr and to see if any further improvement is required.

If a true square-law detector and indicator are used, the vswr can be determined fairly accurately by measuring the return loss or change between an infinite vswr and the unit under test. Typical values are shown in **table 1**. If nonlinearities are present (such as would be caused by using the simple indicator in **fig. 11**), a comparison can be made with known mismatches and the results compared to the test values. It should be noted that coaxial attenuators make excellent mismatches – the return loss is simply two times the attenuation value. An unterminated 3 dB attenuator, for example, yields 6 dB return loss (3.01:1 vswr per **table 1**).

A 1:1 vswr is a luxury[5] that you may not be able to afford, especially if you operate over a wide band of frequencies (such as 144 to 145 MHz). In addition, aging and weather can often affect the vswr. Therefore, you should strive for 1.5:1 vswr as a goal (approximately 14 dB return loss). This is most easily tested by substituting a 75-ohm load in a 50-ohm system. If the return loss of the antenna under test is better than the 75-ohm load (greater than 14 dB) you can stop making adjustments. If return loss is less than 14 dB, more work is required.

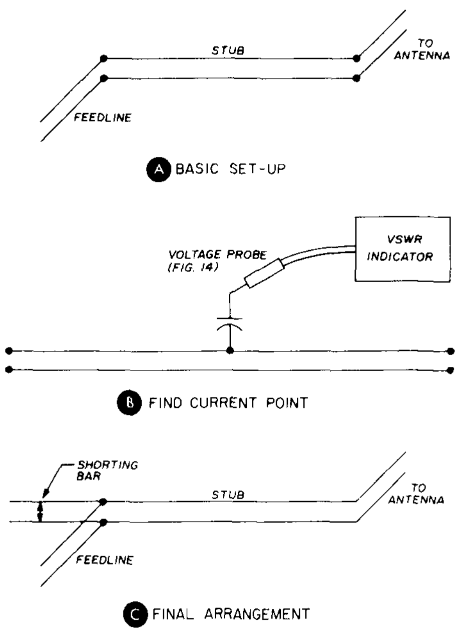


fig. 13. Basic system for matching an antenna to a feedline with a stub. First remove the shorting bar and attach the feedline to the bottom of the stub (A). Feed rf power to the stub and, using a voltage probe, find the voltage minimum (current maximum) which is nearest to the antenna (B). Place the shorting bar at the current maximum point and reconnect the feedline approximately 0.05 wavelength above the shorting bar. Then move the feedline up and down the stub for lowest vswr. When the vswr has been nulled, the null can be enhanced by slightly moving the shorting bar.

Sometimes it is inconvenient to place a balun right at the antenna feedpoint, especially when using stubs. If this happens, you can use tuned lines between the antenna feedpoint and the balun as shown in **fig. 12**. The transmission line impedance of this extension is not important (250 to 400 ohms is recommended) if the line length is a one-half wavelength or a multiple thereof, using **equations 3** or **4**. If open-wire line with only a few insulators is used, a physical length of 95 to 98 per cent of the electrical free-space wavelength is recommended.

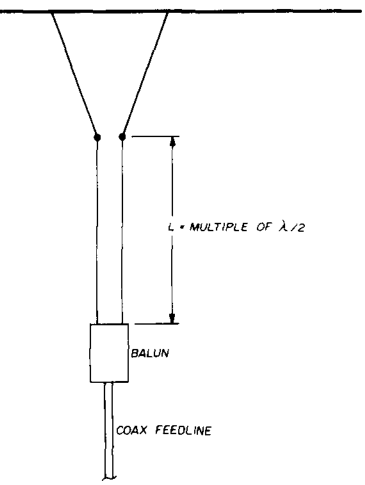
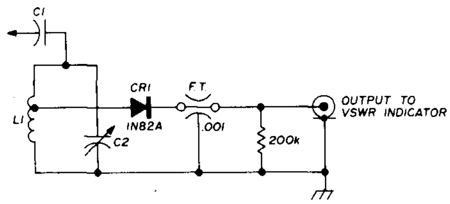


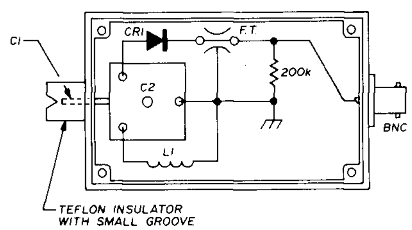
fig. 12 If it is inconvenient to place a balun right at the antenna feedpoint, tuned lines can be used as shown here. If the line is one-half wavelength long (or a multiple) the impedance of this extension is not important (250 to 400 ohms is recommended).

This technique should not be stretched beyond one or two wavelengths because errors are additive, so length becomes more critical.

Although many amateurs are somewhat afraid of matching stubs, they are quite versatile and really not that mysterious. Usually a 1.1:1 match can be easily obtained if the right procedures are followed. First, a matching stub should be at least one-half wavelength



CIRCUIT



CONSTRUCTION

C2	1-6 pF for 432 MHz (value depends on frequency)
CR1	1N82A or similar detector diode
L1	2 turns no. 18 (1.0mm), ¼" (6.5mm) diameter, ¼" (6.5mm) long, tapped 3/4 turns from ground end.

fig. 14. Circuit for a sensitive rf voltage probe (A) and method of packaging the circuit in a Pomona 2417 shielded chassis box (B). L1-C2 resonate to the frequency of interest. Capacitance at C1, provided by the gap between the probe and the transmission line should be as small as possible

long. However, if the shorting bar does not fall exactly at the lower end, a match may not be possible. Therefore, a full wavelength is recommended. If this is not possible, an appropriate length of line can be placed between the stub and the device to be matched to place the shorting bar at a convenient place on the stub. This is a handy technique for tight spots (such as the middle of an EME array).

Probably one of the biggest reasons amateurs avoid stubs is the cut-and-try approach that is required to find the proper lengths. However, matching time can be greatly reduced if a few simple tests are performed (such as those suggested to me by W6VSV from the late W6GD). The first step is to determine approximately where the shorting bar is to be placed. To find this point, proceed as follows:

1. Remove the shorting bar.
2. Attach the feedline to the bottom of the stub (see **fig. 13**).
3. Feed rf power to the stub from a modulated signal source.
4. Using a voltage probe, find the minimum point (current maximum) which is nearest to the antenna. If this point is too close to the antenna end, either shorten the feedline to the antenna or move further down the line to the next current maximum point.
5. Place the shorting bar at the current maximum point.

Next, reconnect the feedline approximately 0.05 wavelength above the shorting bar and move the feedline up or down the stub for the lowest vswr. Then move the shorting bar slightly to enhance the vswr null. Repeat these steps until a suitable match is obtained. The entire procedure is quite simple and takes longer to explain than it does to accomplish!

A simple voltage probe is shown in **fig 14.** It can be easily built into a Pomona 2417 or equivalent shielded box. In this circuit L1-C2 are tuned to the frequency of operation. When used with the low-power test set-up and sensitive vswr indicator, this provides a very sensitive voltage sensor. When using the device make sure that the hot end of the probe does not touch the feedline. The groove in the Teflon insulator maintains the spacing between the probe and the line and facilitates moving the probe along the line.

gain measurements

By now you have probably guessed that the equipment described here can also be used to measure antenna gain. However, that subject is beyond the scope of this month's column, so will have to wait until another time. In the meantime, if you want to read about antenna gain measurements that can be done with the simple test equipment I have described, I recommend that you read references 6 and 7.

summary

It is hoped that this two-part series on vhf/uhf antenna matching techniques will tempt you to do more work on your antennas. The test equipment described here is a *must* for serious-minded vhf and uhf operators — it will more than pay for itself after a few antenna-matching sessions. And, if you use these techniques, you will no longer have to worry about rf burns or the hazards of rf radiation.

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ham radio

carrier-operated relay

for repeater linking

An improved COR using ICs with dual-channel options for linking two repeaters

New concepts and new devices have been developed since the original carrier-operated relay article appeared in these pages.[1] The FCC has approved linking of repeaters, so we've included an addition to the COR that will link repeaters or that can be used for other applications as well.

The basic purpose of a COR is to operate a repeater, so the COR must be as simple and reliable as possible. Other uses for the COR are in a guard receiver for repeater input channels and for speaker muting.

The basic COR circuit **(fig. 1A)** will handle most repeater requirements. The link, or two-channel COR, shown in **fig. 1B** can be used for linking two repeaters, for a remote base, or for a guard channel for your repeater. Both circuits have a common front end. Circuit boards are available, including a fully adjustable time-out timer and input-sensitivity control.*

circuit description

Referring to **fig. 1**, transistors Q1, Q2 are connected as a darlington amplifier for negative-going control signals, as found in a vacuum-tube receiver. The high impedance of the darlington amplifier closely matches the impedance of most tube receivers. For positive-going control signals, normally found in transistorized receivers, make the following changes: R1 to 27k, R2 to 100k, and R3 to 47k. Connect R3 to ground, Q1 emitter to ground, and Q2 base to Q1 collector. The circuit will then respond to positive-going control signals.

U1 is a dual Schmitt trigger that provides positive on-off action. When a control signal is received, ST1 will receive a high from Q2 and a low will appear on its output; this action will set the trigger of timer U2. The low from ST1 is passed to the input of ST2, causing a high to appear on its output, which enables the timer. Time-out is controlled by the setting of R8 and the value of C3.

When the timer starts, its output, pin 3, goes high and energizes the relay. If the input is held long enough, the timer will time-out and pin 3 will go low. However, if the input is released before time-out occurs, the timer output is again driven low and the relay will open. Each time the relay is energized, the timer will have been reset through the action of ST1.

applications

Fig. 2A shows how easy it is to connect this circuit into a receiver and transmitter to control a repeater. **Fig. 2B** illustrates another use for this circuit. Say you'd like to monitor a repeater or simplex channel for any calls, but you don't want to listen to all the yack-yack going on while you're watching your favorite TV show. Set the timer for about five seconds and when a call comes in, the first few words will be at normal volume. Then, in five seconds, the volume will drop to a low level (determined by the setting of the variable resistor). If the call is for you, simply disable the circuit for normal listening level.

If you wish to control two channels, such as a link repeater or a guard receiver for your repeater, merely add the circuitry shown in **fig. 1B.** In this configuration we will use the same basic carrier-operated relay shown

*Basic COR board: $4.50; basic COR kit with board: $12.00; link COR kit with board: $19.50. Order from Circuit Board Specialists, 3011 Norwich Avenue, Pueblo, Colorado 81008.

By Robert C. Heptig, KØPHF, and Robert D. Shriner, WAØUZO, Box 969, Pueblo, Colorado 81002

in **fig. 1A** and add a simple search-lock feature constructed from a single SN7400 and a few other components. Note that R4 (**fig. 1A**) is changed to 100 ohms, 1 watt for this application.

Gates 1 and 2 of the SN7400 are connected as a simple oscillator, and the output is fed through C9, C10 to gates 3 and 4, which are set up as a dual D flip-flop. Transistor Q3 acts as the lock to stop the oscillator. When no signal is applied to the system, ST1 output is

channels of the link repeater A and B (**fig. 2C**). Channel A will be set up to receive 94 and transmit on 28. Channel B will receive on 88 and transmit on 34.

When a signal out of the 34/94 machine is received by the link, the signal will be retransmitted automatically on 28 into the other repeater and will come out on 88. As soon as the signal drops out, the search feature will start up again, and if an answer comes back from the 28/88 machine, this signal will be retransmitted through

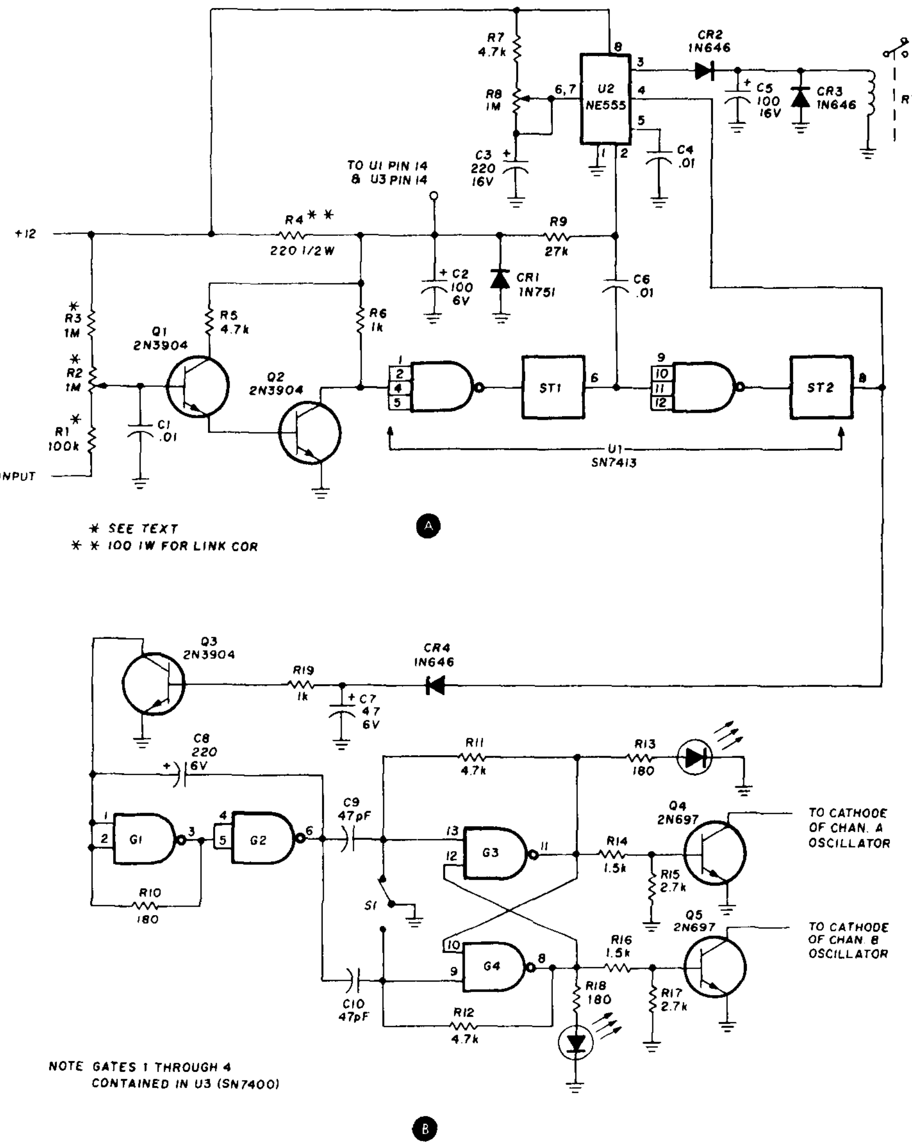


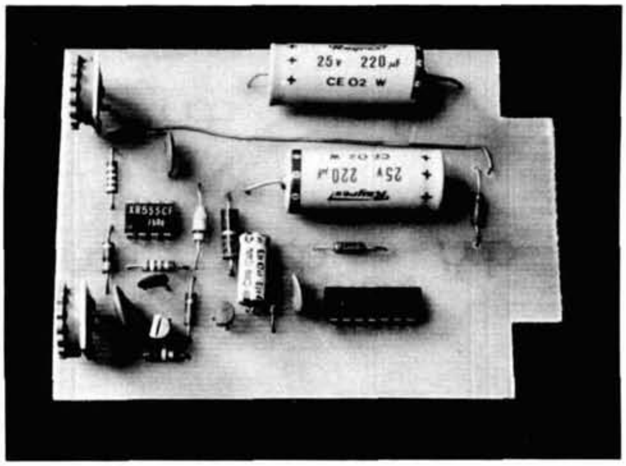
fig. 1. Basic circuit of the COR (A) and simple search-lock feature (B) to control two channels such as a link repeater or guard receiver.

low and Q3 is turned off. This action allows the oscillator to operate and causes transistors Q4, Q5 to conduct and switch on channels A and B respectively.

If a signal is presented to the receiver, the relay will close, causing the repeater transmitter to come up. The oscillator will stop on the channel that was received. As an example, let's say you desire to link a 34/94 repeater into a 28/88 repeater. For simplicity we'll call the two

the 34/94 machine. The action of the basic COR and time-out timer will remain the same as previously described.

How about a guard receiver for your repeater? Refer to **fig. 2D**. Let's say you have a 34/94 repeater and desire to install a receiver on 94 that won't allow the repeater to come up if the output frequency (94) is in use. Install a second oscillator in your repeater receiver



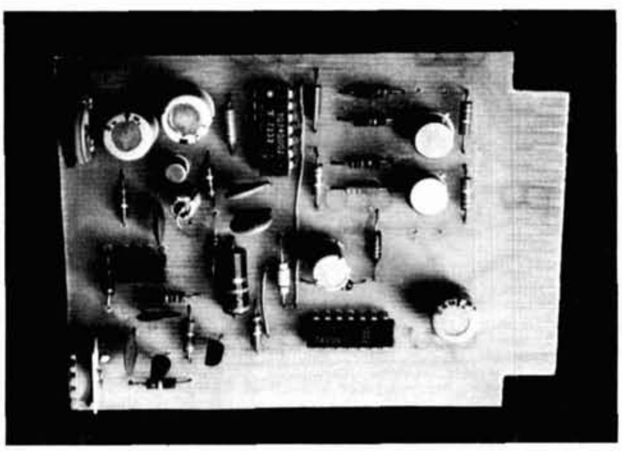
Basic COR component layout. Circuit will handle most repeater requirements. A fully adjustable time-out timer and input-sensitivity adjustment are included.

(channel B) and connect your relay as shown. Diode separation is used to prevent interaction between oscillator and COR. If a signal is not present on 94, the repeater will operate in a normal manner; but if a signal is present then the COR will lock on to channel B and the repeater can't be brought up, simply because the input-channel oscillator (34) is disconnected.

trouble shooting

In the event of trouble use a dc scope or a vtvm to check for the following voltages. (All voltages are given assuming a negative-going signal into the system). First check the supply voltage (+12V) and the voltage to the ICs (+5V). Check Q2 output. It should be close to zero volts with the input open and should rise to near +5 volts with the input grounded and R2 at maximum sensitivity. If not, and Q1 and Q2 are both good, replace Q1, as any slight leakage here will affect the circuit.

To check U1: pins 1, 2, 4, 5 and 8 should be near zero volts with the input open, and pins 6, 9, 10, 11 and 12 should be near +5 volts. These readings should reverse when the input is grounded; if not replace U1.



Added components for a search-lock feature to allow two-channel operation, such as repeater linking.

To check U2: pin 3 should be near zero volts with the input open. Ground the input, and pin 3 should go high (12V); pin 4 will be high (5V). Connect the scope or vtvm to pins 6 and 7. The voltage should rise slowly to about 8 volts, the timer will fire, and pin 3 will go low. If not, replace U2, R7, R8 or C3 in that order.

To check U3: pins 1, 2, 3, 4, 5 and 6 should show a clock pulse of about 2 pulses per second. If not, replace U3, Q3, C8 or R10 in that order until clock is obtained. Probe pins 8 and 11. They should alternately switch from zero to +5 volts. If not replace U3, C9, C10, R11 or R12 in that order until the function is obtained.

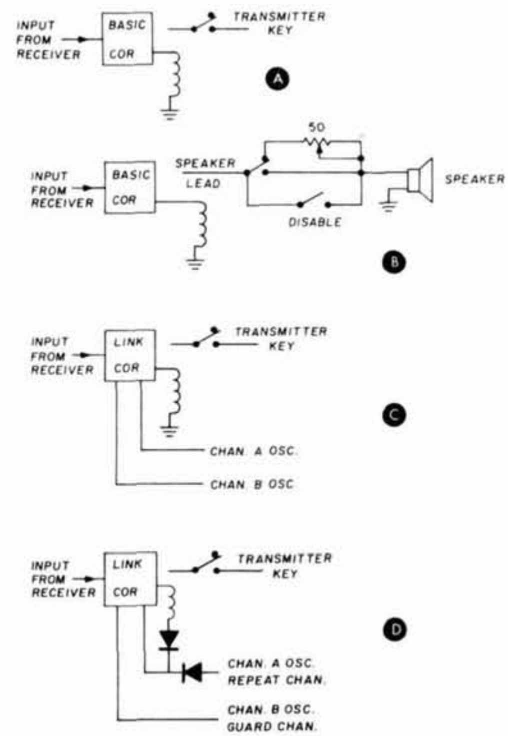


fig. 2. Applications of the COR as a simple repeater (A), for speaker muting (B), as a link repeater (C), and as a guard receiver (D).

By making simple modifications the circuit can be easily tailored to your own requirements. For instance, by increasing the value of C1, a delay activating the system will be noted. Increase the value of C5 to delay the dropout. Decrease the value of C8 to speed up the clock or search rate.

Several of these carrier-operated relays have been constructed and are in use in our area. We've found that others are amazed at the simplicity of the circuit and how well it works for them in their particular application. This circuit is just another example of putting those little plastic centipedes to work for amateur applications.

reference

1. Robert C. Heptig, KØPHF, and Robert D. Shriner, WAØUZO, "Carrier-Operated Relay," *ham radio*, November, 1972, page 58.

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MICROPROCESSORS

microcomputer interfacing: substitution of software for hardware

A reader who has followed the current literature on microcomputers will frequently encounter phrases such as "hardware/software tradeoffs" or "substitutions of software for hardware." These phrases are strongly indicative of anticipated applications for microcomputers in the near future and do much to explain why industry is so excited about them. In this month's column we discuss how to substitute microcomputer software for hardware.

hardware Mechanical, magnetic, electronic, electromechanical, and electrical devices from which a system is fabricated.

software Totality of programs and routines used to extend the capabilities of computers, such as compilers, assemblers, narrators, routines, and subroutines.[1]

In our specific case, software represents the machine-language program stored within the memory of a microcomputer. Hardware represents the specific devices that store, manipulate, receive, or transmit digital information. The microcomputer itself is included in our definition of hardware. The basic point of this month's column can be simply stated:

Through skillful programming, it is possible to substitute machine-level routines and subroutines for specific hardware devices that store, manipulate, transmit, or receive digital information. This activity is called the substitution of software for hardware.

Typical replaced hardware includes knobs, buttons, pulsers, switches, logic switches, clocks, and small memories as well as TTL integrated circuit chips that perform digital functions such as debouncing, sequencing, shifting, adding subtracting, comparing, and logic operations on multibit digital words. Hardware *not* usually replaced includes simple TTL chips such as inverters, flip-flops, gates, latches, three-state buffers, and counters.

Fig. 1 illustrates the basic tools you would employ in the substitution of software for hardware:

1. Programming.

2. The use of synchronized data appearing on the bidirectional 8-bit data bus, D0 through D7.

3. Input and output synchronization pulses called *device-select pulses.*

4. *Interrupts* to the microcomputer.

In an 8080-based microcomputer, you can generate 256 different input and 256 different output synchronizing pulses. If you need more pulses, you can always employ memory I/O techniques as discussed in last month's column. You therefore have an unlimited number of synchronizing pulses with which to coordinate the behavior of almost any type of digital electronic circuit. As you substitute software for hardware, your main tradeoff will be speed of operation. It is useful to remember the following rule:

In the substitution of software for hardware, the key tradeoff is speed of operation. The execution of any computer instruction takes time; the more instructions used, the longer it will take to execute them.

This tradeoff is not as serious as it may seem. Present 8-bit microcomputers are very fast, and future microcomputers will be at least ten times faster. The majority of existing electromechanical machines are slow by digital electronic standards. The human senses cannot participate in activities that require millisecond time resolutions; i.e., in an input/output sense, we are very slow machines.

Table 1 summarizes some of the more commonly

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encountered situations where hardware such as debounced pulsers, switches, logic switches, and clocks are replaced by simple wire connections, latches, flip-flops, and inverters. We have provided abbreviated versions of the required software. (See reference 2 or previous columns in *ham radio* for details on the generation of the *out n* pulses, where *n* is an octal number between 000_8 and 377_8).

A timing loop is a short subroutine that generates a precise time delay, typically greater than 100 microseconds. As the table shows, the replacement can be made in most cases by the use of one or two different device-select pulses. A pair of *out n* instructions that bracket a timing loop are sufficient, when applied to a SN7474 flip-flop, to produce a monostable pulse of precise time duration. The addition of a second timing loop and a jump instruction, JMP, changes the flip-flop output to that of a variable duty-cycle clock, the duty cycle being controlled by the relative time delays of the two timing loops.

Of particular interest is entry 6 in the table, in which an eight-position mechanical switch or eight individual mechanical switches are replaced by an 8-bit control word strobed into an 8212 chip from the accumulator with the aid of a device-select pulse. This control word is latched by such an action and can subsequently influence the behavior of a rather sophisticated digital circuit. The 8212 chip therefore functions as a *control register* for the circuit. We have directed your attention to this principle because it is now being widely used in an exciting new generation of *interface chips* that reduce the number of wire connections needed between a microcomputer and an external device. The 8255 programmable peripheral interface chip described in last month's column is included in this category.

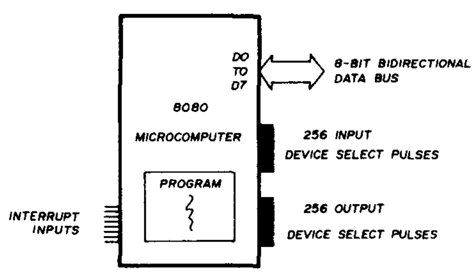
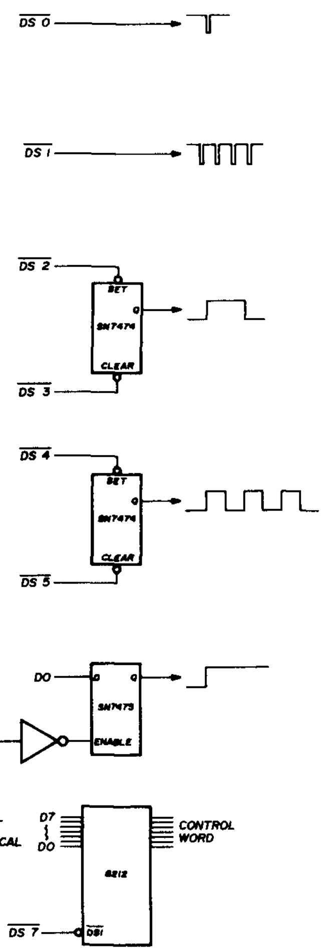


fig. 1. The basic microcomputer tools required for the substitution of hardware by software.

Table 1 provides only a few examples of how hardware can be replaced by simple software with the aid of device-select pulses. Omitted from the table are the more obvious hardware substitutions: arithmetic logic units (SN74181), digital comparators (SN7485), and shift registers (SN74194, SN74198, SN74199). Such chips are replaced by microcomputer instructions that add, subtract, compare, and shift the 8-bit contents of the accumulator register.

table 1. Some uses for device select pulses in the substitution of hardware by software

SUBSTITUTED HARDWARE FUNCTION	NEW HARDWARE CIRCUIT	SOFTWARE EMPLOYED
1. PULSER, 500 nS MONOSTABLE.	DS 0	OUT 0
2. LOW DUTY-CYCLE CLOCK (500 nS PULSES).	DS 1	OUT 1, TIMING LOOP, JMP
3. DEBOUNCED PULSER, MONOSTABLE, LOGIC SWITCH.	DS 2, SET, Q, SN7474, CLEAR, DS 3	OUT 2, TIMING LOOP, OUT 3
4. VARIABLE DUTY-CYCLE CLOCK.	DS 4, SET, Q, SN7474, CLEAR, DS 5	OUT 4, TIMING LOOP, OUT 5, TIMING LOOP, JMP
5. ONE BIT OF CONTROL INFORMATION FROM A MECHANICAL SWITCH.	DO, D, Q, SN7475, ENABLE, DS 6	MVI A CTRL, OUT 6
6. EIGHT BITS OF CONTROL INFORMATION FROM A SET OF EIGHT MECHANICAL SWITCHES.	D7 } D0, 8212, DSI, DS 7, CONTROL WORD	MVI A CTRL, OUT 7



Although the microcomputer is the most revolutionary electronic device since the invention of the transistor, it is not always obvious how a microcomputer can be used in an amateur radio station. To help lead the way we would like to encourage those that are using microcomputers in amateur stations to drop us a note on how they are being used with the idea of writing a guest column in this section of *ham radio*. Alternatively, you may want to submit a full construction article or even a short note that could be included in one of our regular columns.

references

1. Microdata Corporation, *Microprogramming Handbook*, Santa Ana, California, 1971.
2. *Bugbook III. Microcomputer Interfacing Experiments Using the Mark 80R Microcomputer, an 8080 System*, E&L Instruments, Inc., Derby, Connecticut, 1975 ($14.95 from Ham Radio Books, Greenville, New Hampshire 03048).

ham radio

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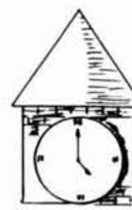

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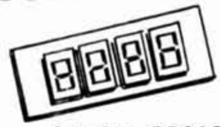

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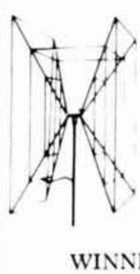

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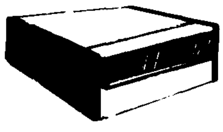

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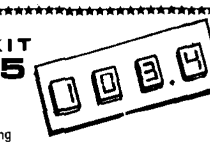

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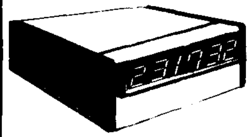

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4009	-.59	4024	-.99	4044	-.59
4010	-.55	4025	-.24	4047	-.59
4011	-.24	4026	-1.49	4049	-.59
4012	-.24	4027	-.59	4050	-.59
4013	-.59	4028	-.99	4066	-.99
4014	-1.49	4029	-1.39	4077	-.39
4015	-1.19	4030	-.49	74C02	.29
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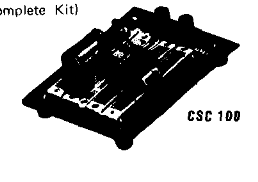

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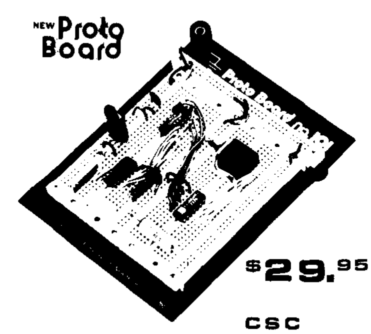

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micro-TO keyer mods

The schematic of **fig. 1** shows a simplified and improved version of this popular keyer. The three transistors that made up the pulse generator were replaced with an NE555V (U1). Normally a free-running oscillator, the NE555V becomes a switchable dot generator by adding CR1, providing an accurate 1:1 ratio.

A variable dash circuit was added using an SN7473 (U2). When U1-12 is high, forming dashes, U2-13 is low, providing a load for U1-7. Voltage then decreases at U1-2, 6, 7; consequently dash length will be extended and may be controlled by the potentiometer shown. In the dot position, CR2 prevents feedback so that dot/space ratio is always 1:1.

The sidetone generator was replaced by another NE555V (U4), which has a tone range of about three octaves. The output easily drives a 3-watt, 4-ohm speaker (no extra speaker is used for the keyer). Still another NE555V (U5) was added to U4 to provide a two-tone oscillator for ssb tuning. A 16-pin IC socket will simplify construction. External components of U5 may be chosen for a suitable fixed frequency, while U4's tone control may be varied to obtain a suitable second frequency and marked for presetting. If you wish to omit the pushbutton switch and U5, connect the 1N914 directly to U4, pins 2 and 6.

The output section consists of Q1 and Q2. The keying bias of my transmitter (an FL-DX500) is -26 volts at 5 mA, easily handled by Q2. Q1 is an inverter for Q2. The resistor across Q1's emitter-collector junction and the capacitor in the base circuit provide a good-sounding on-the-air signal.

The rotary multiswitch connects the receiver output to a speaker or headset. In either position, sidetone can be added by adjusting the volume control while listening to a desired signal. Keying speed and ratio are quickly adjusted, the volume control is turned to zero (no tone), and the transmitter is ready for keying.

The keyer circuit is mounted on a 3-3/16 by 1½ inch (80 by 40mm) perf

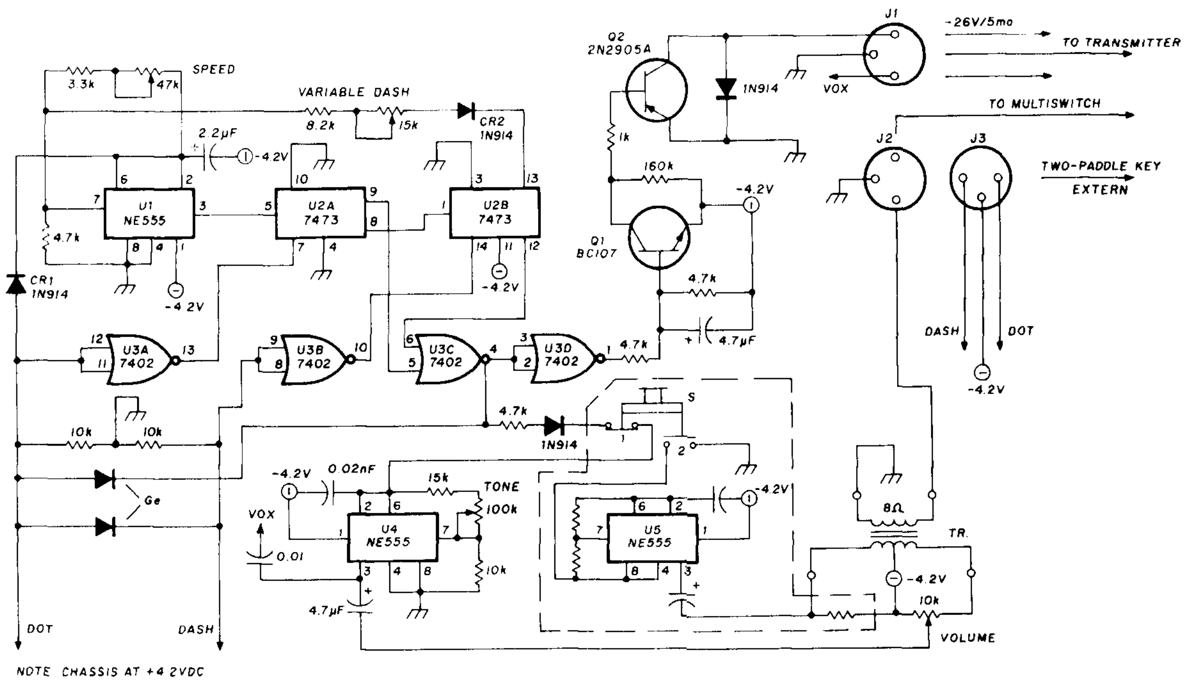

fig. 1. Improved micro-TO keyer. Transformer is a small transistor-radio unit. Keyer speed is about 3-50 wpm; dash ratio can be varied about 5:1. Dot ratio is fixed at 1:1.

board, with space remaining for more components. The transformer is mounted at the inside rear of the box near its jack.

Herbert Seeger, DJ9RP

stabilization of the Ten-Tec KR20 keyer

A nagging problem with the Ten-Tec model KR20 keyer during four years of use has been an intermittent dit when the keyed character was a dah. Persistent checking showed no component failure. Finally, by monitoring the output of the power supply, a 0.5-volt shift was discovered in the output voltage while keying. This annoying problem vanished and the shift was eliminated when the 270-ohm resistor between the base and ground of Q6 was replaced with a 5.6-volt zener (**fig. 2**).

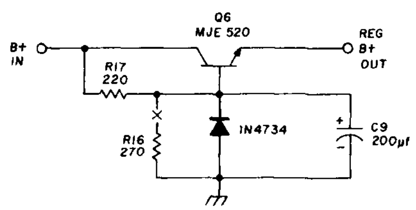

fig. 2. Method for stabilizing the Ten-Tec KR20 keyer.

Don Peck, W3CRG

AFSK generator

I recently built the excellent crystal-controlled AFSK generator described in *ham radio** but since I didn't have a +15 volt power supply available, I used the TTL oscillator circuit shown in **fig. 3.** The crystal is an FT243 that I hand ground to 4589.5 kHz. The 50-pF series capacitor allows the frequency to be trimmed to exactly 4590 kHz.

The output of the TTL oscillator was *connected to a divide-by-10* 7490 IC and then to pin 1 of U1A in the AFSK circuit.

The output oscillator was connected to a divide-by-10 7490 IC and then to pin 1 of U1A in the AFSK circuit.

I installed two miniature transistor transformers at the output of U4B, using the two high-impedance windings connected in series, tuned to 2210 Hz. The output was then connected to the microphone input to my KWM2 through a 22k/100 ohm divider. The output wave-form is very satisfactory and on the air tests were excellent.

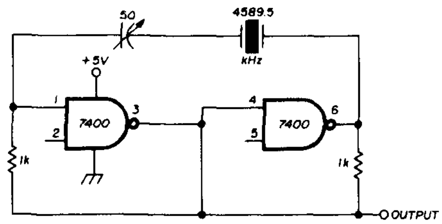

fig. 3. Simple TTL oscillator uses 7400 IC.

Jean Nugues, F8KI

*Howard Nurse, W6LLO, "Crystal-Controlled AFSK Generator," *ham radio*, December, 1973, page 14.

vlf converter

An interesting article appeared in the November, 1974 issue of *ham radio*† describing a very-low-frequency converter with a tuned circuit using magnets and a toroid. The converter shown in **fig. 4** uses a lowpass filter instead of the usual tuned circuit so that the only tuning required is with the receiver.

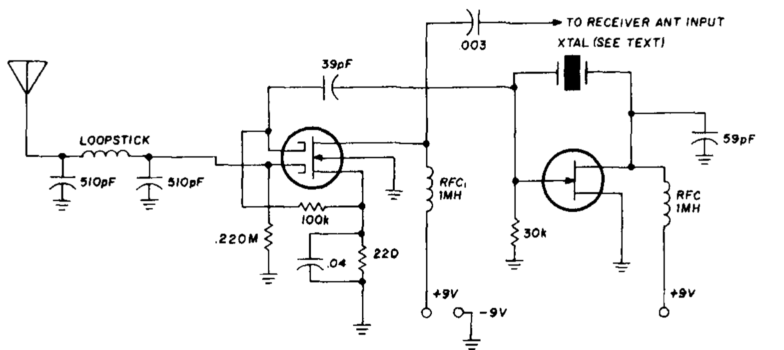

fig. 4. Vlf converter using untuned input.

Despite its simplicity the converter has a measured threshold sensitivity of about 20 microvolts, which is ample for these frequencies. The dual-gate mosfet and fet used in the mixer and oscillator aren't critical. Any crystal having a frequency compatible with the receiver tuning range may be used. For example, I use a 3500 kHz crystal; hence 3500 kHz on the receiver dial corresponds to zero kHz; 3600 to 100 kHz, 3700 to 200 kHz, etc. At 3500 kHz on the receiver all you can hear is the converter oscillator, and vlf signals start to come in about 20 kHz higher.

R. N. Coan, W3CPU

†Guenter Ruehr, OH2KT, "Tuned Very Low-Frequency Converter," *ham radio*, November, 1974, page 49.

tube shields

Many older pieces of gear, such as my 75A4 receiver, use tube shields to isolate various stages. These shields can cause instability if they no longer make good contact with the tube socket.

While this is easily cured by cleaning and by deforming the shield slightly to insure a tight mechanical connection to the socket, a far better course is to replace the shields with one of the more modern tube shield designs.

The old style shields were ineffective at best in helping cool the tubes and often actually caused envelope temperature to rise in local areas, leading to reduced performance and shortened tube life.

The modern shields are easily identified — they are generally black on the outside and feature fluted spring-metal fingers of one sort or another on the inside. These shields substantially lower tube temperature while retaining the isolation characteristics. The old style shields, on the other hand, usually have a metallic finish, and lack any form of heat dissipating fingers on the inside.

Replacement of the old style shields with the more modern variety will give a worthwhile improvement in overall tube life, and will help the tube maintain its new specs longer. The investment is a modest one and well worthwhile.

Bob Locher, W9KNI

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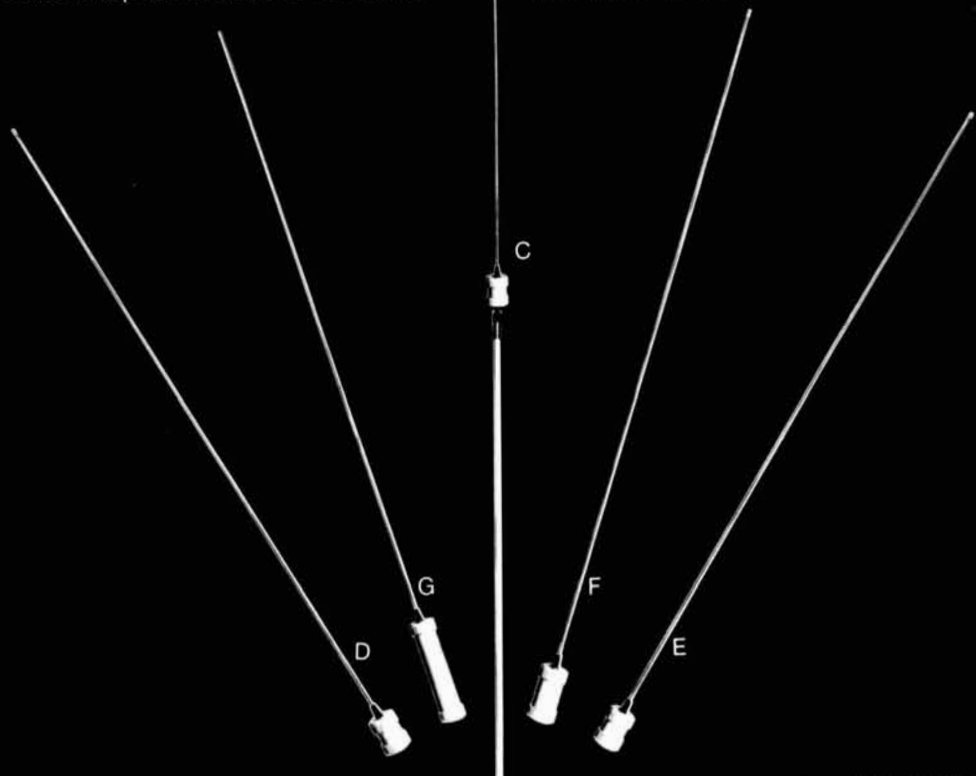

A/B

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- (D) 15 meter coil/antenna **Model 281**
- (E) 20 meter coil/antenna **Model 282**
- (F) 40 meter coil/antenna **Model 283**
- (G) 75/80 meter coil/antenna **Model 284**

Quick disconnect unit **Model 531**
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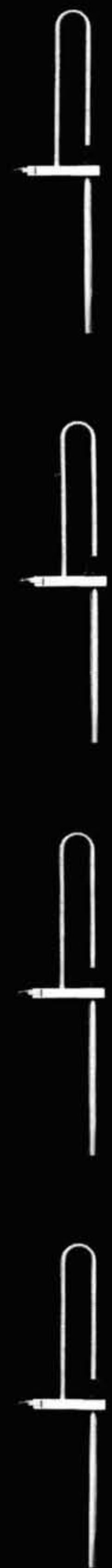

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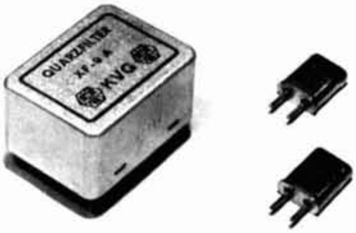

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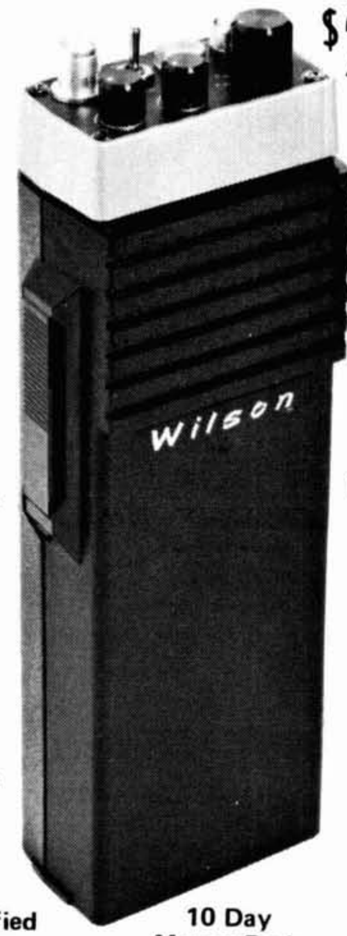

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Don Roehrs, President of Signal One, and the CX-11 grand prize.

1976 ham radio sweepstakes winners

WAØQZW is the grand prize winner — eight others win either Atlas transceivers or Icom IC-230s

Ham Radio's seventh annual Sweepstakes was by far the biggest ever with nine very happy winners and a very tired staff, both here, and at our local Post Office.

Well over 30,000 entries were received this year, along with many questions about the new Signal/One CX-11, the Icom IC-230 and the Atlas 210X transceivers.

Certainly the greatest interest was focused on the grand prize of the new Signal/One transceiver. Just what is there in that magic box to make it cost $4000? When Don Roehrs, President of Signal/One, personally delivered this prize we were almost as eager as its winner to see what it was all about. We certainly were not disappointed, to say the least.

The CX-11 represents a complete redesign of the earlier models, from a new front-end design in the receiver to a brand new, solid-state final amplifier. Virtually every stage of this intricate radio is either completely new or extensively revised. When you look inside you find almost nothing that looks familiar. The painstaking care that was put into this package should really pay off in both performance and reliability.

We've talked with Randy Powell, WAØQZW, the winner of the Signal/One after he received it and he could hardly believe what an exciting and complete package he had won.

Next on the winners list were the four lucky recipients of the Icom IC-230 synthesized two-meter transceivers including Glen Galati, WBØAXK; Dave Mitchell, WA3CPC; Bob McCarthy, WA1UVX; and Helen Haynes, WBØHOX.

The IC-230 has really made quite a name for itself in the past couple of years. Using a phase-locked-loop synthesizer it covers all the standard 30-kHz repeater pairs and is easily adapted to the 15-kHz "split" channels.

Perhaps the most exciting part of this radio is its very sensitive receiver which includes a five-section helical resonator type front-end filter to insure an absolute minimum of intermod problems. When all of this is put into a package no larger than most crystal-type rigs you end up with one of the most popular 2-meter fm rigs on the market today.

The final group of winners received Atlas 210X transceivers. Included on this list were Chester Koziol, WA2BGS; Robert Trotter, K7VQG; Harry Newport, WØJDP; and Herb Frosell, K2IB.

The versatile Atlas features 200 watts dc input to an all solid-state, broadband, no tune-up final. It operates on 80 through 10 meters and offers one of the best receivers available. Extremely small in size and running on 12 Vdc the Atlas is one of the best mobile rigs around today; with an ac supply it is easily adapted to home-station use.

This year's contest was certainly the most work yet (and the most fun yet) for all of us here at *ham radio*, and we certainly want to thank all of you who gave the time and effort to enter. We'll look for *your entry* next year when we draw the grand prize.

ham radio

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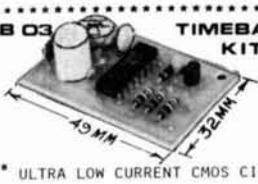

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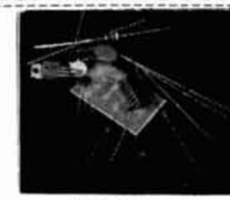

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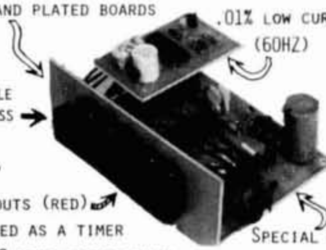

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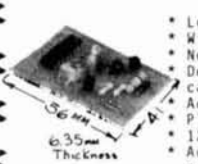

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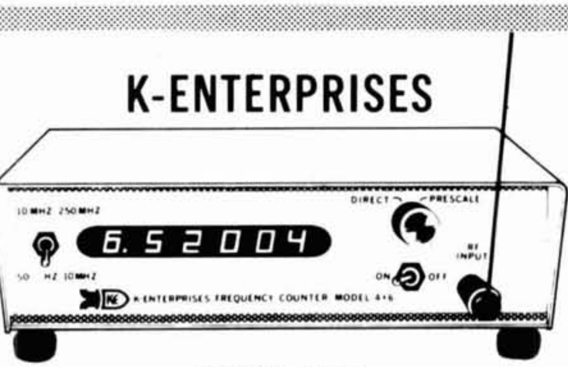

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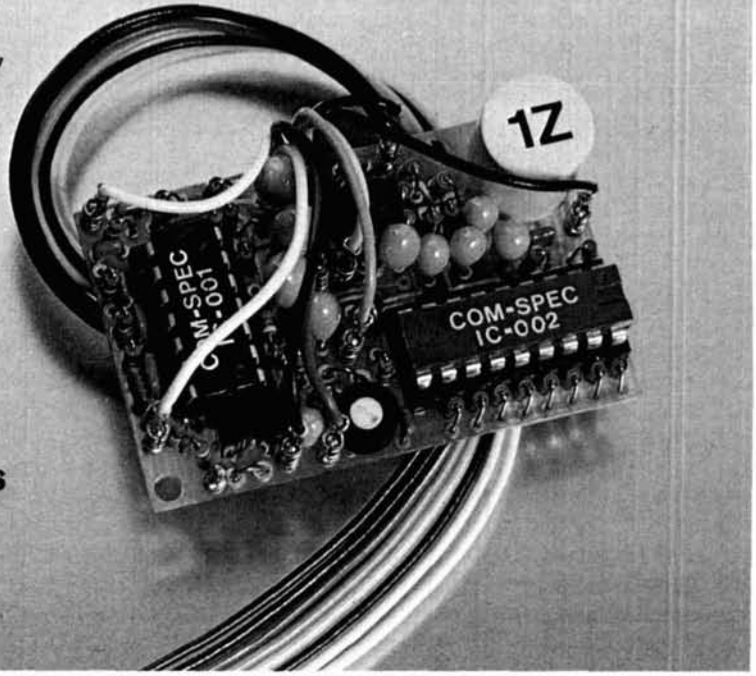

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radio engineers in the world, and founder of Southcom International located in Southern California. Southcom is one of the leading manufacturers of commercial and military radio equipment sold throughout the world. Atlas transceivers' immunity to overload and cross modulation from strong signals is nothing short of fantastic, and is a result of the advanced state-of-the-art designs by Les, and licensed to Atlas by Southcom.

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The new ultra-modern fully solid-state TRITON makes operating easier and a lot more fun, without the limitations of vacuum tubes.

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NEW products

laboratory-grade test instruments

Continental Specialties Corporation has developed three new test instruments to aid the professional engineer, student, or hobbyist in solving electronic design problems. Called Design Mates, these instruments are not kits but are completely wired, fully tested, and ready to use. They are available for immediate delivery from local distributors or from the manufacturer.

Design Mate 1 allows you to build any circuit using no. 22 AWG (0.6mm) solid hookup wire for connecting discrete components, including transistors and ICs in TO-5 or dual in-line packages from 8 - 40 pins or more. No solder is needed for connections because components fit into an appropriate socket and bus strips. Easy in, easy out for circuit testing. Also included is a regulated power supply (5 - 15 volts dc up to 600 mA). You can monitor supply voltage with a built-in voltmeter or use the meter to monitor voltage on the circuit under test. Design Mate 1, wired, tested, and ready to use sells for $49.95.

Design Mate 2 is a full function generator designed for troubleshooting and circuit-design testing. It features three waveforms and a short-proof output amplifier, which provides variable signal amplitudes and constant output impedance. It can be used to test audio amplifiers, operational amplifiers, and prototype circuit designs. It's versatile enough to handle complex industrial electronic design problems. Complete with instruction and operating manual, Design Mate 2 is priced at $64.95.

Third in Continental's new instrumentation series is Design Mate 3, a low-cost R/C bridge. Takes the guesswork out of deciphering component values with unreadable markings. You can measure component values to an accuracy of better than 5 per cent using only two controls and a unique solid-state null detector. Null-detector output is determined by two high-intensity LEDs. Design Mate 3 completely wired, tested, and calibrated, with technical data, is priced at $54.95.

Also available from Continental is a matching blank utility box. You can use it to house instruments of your own design whose appearance will match the Design Mate family. The utility box is the same size and shape as the Design Mate instruments. It's made of durable, high-impact, high-temperature plastic and is furnished with predrilled metal bottom plate and mounting hardware. The utility box sells for only $5.50.

For comprehensive specifications on the three Design Mate instruments, a 20-page illustrated catalog is yours for no charge. Write Continental Specialties Corporation, 44 Kendall Street, Box 1942, New Haven, Connecticut 06509, or Box 7809, San Francisco, California 94110, or use *check-off* on page 118.

125 Hz crystal filter for Drake R-4C

Sherwood Engineering has recently announced the availability of a crystal filter, 125 Hz wide at the 6 dB points, designed specifically for the Drake R-4C communications receiver. The new filter is completely compatible with the standard accessory filters offered by the R.L. Drake Company, and is being marketed as an adjunct to those with more standard bandwidths.

The new 8-pole crystal filter, the Sherwood model CF-125/8, has a 2.5 shape factor at the 6 and 60 dB points (bandwidth of about 325 Hz at -60dB), and exhibits less than 1 dB passband ripple. The input and output impedances are 50 ohms. Ultimate attenuation is greater than 100 dB. The 11 dB insertion loss of the CF-125/8 is similar to that of the Drake accessory filters.

For the CW operator who is looking for maximum selectivity, particularly during CW contests, this filter offers a significant improvement in receiving capabilities under adverse operating conditions. Due to careful design, the crystal filter does not display excessive ringing, even with strong signals. One well-known 160-meter operator, who used a CF-125/8 filter during a recent 160-meter CW contest, reported excellent results and concluded that it was one of the finest CW filters ever offered to the amateur community.

The new CF-125/8 carries a full money-back guarantee if you're not satisfied, and is priced at $125 from Sherwood Engineering, 1268 South Ogden Street, Denver, Colorado 80210.

Morse-code reader

The Atronics code reader is a compact, solid-state instrument that decodes Morse directly from your speaker and displays the resultant message in alphanumberic form on the front panel. A choice of readout size is available. The model CR-101 characters are 0.65 inch high by 0.42 inch wide (16.5 by 10.7 mm); model CR-101A characters are 0.2 inch high by 0.15 inch wide (5 by 3.8mm).

All characters, including punctuation, are displayed one at a time. Code speed, on-off, and audio level are set by front-panel controls. The speed control, with settings between 0-10, is used as an indicator only. For any setting, code speeds between 70-140 percent of that setting can be decoded. For example, if the code reader is set for 14 wpm, it will display any code speed between 10-20 wpm.

A light-emitting diode above the speed control indicates the expected length of a received dot. Another light-emitting diode above the level control indicates mark *(on)* and space *(off)*. The only connection required is a line between a phone jack on the code reader rear apron and your receiver speaker

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terminals. Input impedance of the code reader is 1000 ohms.

A radio teletype interface module (model TU-102) is available as an optional accessory. The TU-102 accepts 5-level code (start, five data bits, two stop bits). Teletype speed can be selected for 60, 75, or 100 wpm. Auto features CR, LF, FIG and letters are provided automatically.

The model CR-101 and CR-101A are priced at $225 and $195 respectively; the model TU-102 RTTY interface module is $85.00 (a $10.00 installation charge is made if the TU-102 is purchased separately). For more information write Atronics, P.O. Box 77, Escondido, California 92025, or use *check-off* on page 118.

hand-held scanning monitor

A hand-held scanner is a real convenience when you're walking around and want to keep on top of the action on the vhf and uhf bands. The Electra Company announces an addition to its product line called the Bearcat Hand-Held Scanners. Two models are available, a two-band version covering the low- and high-vhf bands, and a single-band version that covers uhf. Both models feature four-channel operation including LED channel indicators and individual channel lockout switches. Also included are an auto-manual selector switch and a volume and squelch control.

The Bearcats come equipped with a telescoping antenna, but provision for an optional loaded (rubberized) flexible short stub antenna has been included.

Weight is only 11 ounces (312g); size is 6¼ x 1½ x 2¾ inches (16x4x7cm). Four AA type dry cells are used for power. Sensitivity on vhf is 0.6 microvolt; on uhf, it's 1.2 microvolts. Audio output is 250 milliwatts. Scan rate is eight channels per second. Convenience features include a built-in belt clip and jacks for optional external antenna, earphone, battery charger, and ac adapter.

Both Bearcat models are priced at $129.95 (crystals not included). For more information, write The Electra Company, 300 South on East County Line Road, Cumberland, Indiana 46229, or use *check-off* on page 118.

automatic voice identifier

Newly introduced by Racom, Incorporated, is the Series 1500 voice identifier. Featuring high-reliability, all-solid-state circuitry, the Series 1500 uses the patented Racom disc principle (no tape loops) in conjunction with an electric timer that can be programmed in the field. No relays are used, although an option is available for those who might desire a "dry closure."

The Series 1500 can be field programmed to identify after each programmed time period, identify once after the last transmission, or identify after each transmission. Dual transmissions are prevented by a built-in channel monitor that can sense either audio or dc voltages. Operational status can be checked by illuminated indicators on the front panel. You can record any message, such as your dispatcher's voice. An erase interlock circuit ensures against accidental erasure of the recorded message. The Series 1500 automatic voice identifier can be mounted in a rack or on your desk.

Delivery from Racom is 4-6 weeks after receipt of order. For more information write Racom, Incorporated, 5504 State Road, Cleveland, Ohio 44134, or use *check-off* on page 118.

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miniature hole saws

There is an awkward range of hole sizes for electronic sheet metal and PC board material for which a series of miniature hole saws work very well. The Blair Equipment Company offers a set of seven hole saws in steps from one-quarter to five-eighths inch (6.5 - 16mm) with an interchangeable common arbor that obviates any need for drilling a pilot hole first. The arbor has a spring-loaded pilot which recesses into the arbor as the hole saw blade approaches the work, so you don't need a pilot hole for the arbor pilot to pass through. The blades, which are precision made, cut clean continuous chips through metals, shim stock, wood plastics, rubber, cardboard and other materials, leaving almost burrless holes. Each high-speed cutter is good for over 3000 holes in sheet steel and may be used with any ¼-inch (6.5mm) electric drill. The arbor has a high-speed steel automatic center point to avoid the need to center punch. a depth rod adjusts depth of cut up to 3/16 inch (5mm).

Blair specializes in automobile body equipment and markets these saws through stores catering to the auto body repair trade, but they are also available from Brookstone Company, Peterborough, New Hampshire 03458 for $20.95.

IC op amp cookbook

This new book by Walter Jung not only explains the basic theory of the IC op amp in a down-to-earth and easy to read manner, it also shows by example how to effectively use op amps in useful circuit applications. Fully illustrated, this practical book is bound to appeal not just to amateurs, but to anyone who has an interest in modern, linear design techniques — including amateurs, technical and engineering students, and practicing technicians and engineers.

The book is organized into three parts; Part I introduces the IC op amp and discusses general considerations, Part II covers practical circuit applications, and Part III consists of two appendixes of manufacturers' reference material.

Chapter 1 covers basic theory, which includes the ideal and nonideal op amp, with detailed analysis of error sources and dynamic characteristics. Chapter 2 describes early IC innovations, and discusses in detail the circuitry of such popular general-purpose types as the 709, 101, and 741.

Specialized units are also introduced and their general uses discussed. Chapter 3 covers general operating proceedures, such as nulling, frequency compensation, and protection against abuses and failures.

The remaining 5 chapters of the book discuss the application of op amps in such circuits as voltage and current regulators, precision rectifiers, limiters, comparators, logarithmic amplifiers, instrumentation amplifiers, analog multipliers, low-level preamps, active filters and equalization circuits, power booster stages, sine-wave oscillators, multivibrators, function generators, and voltage-controlled oscillators.

Unique IC op amps are also treated, such as programmable op amps, operational transconductance amplifiers, and quad current-differencing amplifiers.

This book is quite a departure from previous works of its subject and style. In terms of depth and content on applications of IC op amps, it is a virtual *tour-de-force*; 591 pages with over 250 circuit diagrams to pick from. And, unlike too many other applications handbooks, the circuits are clearly annotated, with the governing design equations given as well as the particular component values. Throughout the book emphasis is given to selecting the optimum IC for the job.

The book is not a textbook, nor is it a cookbook in the true sense of the word. It is really a "how to" cookbook that reaches the real-world level and approaches design problems as they actually occur. For this reason it is probably the single most valuable book available on IC op amps. If you now use op amps, or would like to, you'll find this book worthwhile. $12.95 from Ham Radio Books, Greenville, New Hampshire 03048.

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RECONDITIONED TEST EQUIPMENT for sale. Catalog $.50. Walter, 2697 Nickel, San Pablo, Ca. 94806.

WANTED: HyGain 400 Roto Brake Rotor or heavier duty rotor. K4EKJ, 1206 E. Lee Rd., Sterling, Va. 22170.

GOVERNMENT SURPLUS Communication Equipment, FREE catalog. Colonel Russell, 9410 Walhampton, Louisville, KY 40222.

AMATEUR CALL SIGN PINS $1.00. 1" x 3". 1 or 2 lines engraved. Blue, black, red, green. Guaranteed. Holly, Box 3926-S, Hollywood, Florida 33023.

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SAVE! Bomar FM, xtals $4.00 ppd. Dentron, Hustler, CushCraft, W. M. Nye, Ameco. Used gear. Complete catalog - write Ferris Radio, 308 E. Harry, Hazel Park, Mich. 48030.

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CLEGG FM27B w/mbl mount, $275. M. Sedlak, Montgomery, Pa., 717-547-1213.

COMPUTER HOBBYISTS! Bargain hunt and sell via ON_LINE. 18 issues/year - $3.75. Free sample issue from: ON_LINE, 24695 Santa Cruz Hwy., Los Gatos, CA 95030.

MANUFACTURERS, DISTRIBUTORS, DEALERS! The Memphis Hamfest had 3,500 registrations last year — even more expected this year! Saturday and Sunday, October 2 & 3, at State Technical Institute, Interstate 40 at Macon Road. Security, motels, restaurants — a great location for a great event! Contact Harry Simpson W4SCF, Box 27015, Memphis, TN 38127. Telephone 901 358-5707.

MOTRAC, U43MHT, 40 watts, 4 frequency, with GLB synthesizer, 5kHz split, illuminated dials, touch-tone, shock mounting, all accessories & manuals. Like new in excellent condition. All for $420 or best offer. Bob Graf, WB9QYX, 218 Rebecca Lane, Normal, Ill. 61761. (309) 452-0329.

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

FREQUENCY COUNTER BOARDS, Jan. 76 HR, double sided glass epoxy includes 500 MHz prescaler circuitry and LED board. Instructions and parts source listing $15.00 complete. Popular Electronic Keyer Board $2.00. CSJ Electronics, 5201 Cameron Court, Lincoln, NE 68512.

PORTA-PAK the accessory that makes your mobile really portable. $59.95 and $39.95. Dealer inquiries invited. P. O. Box 67, Somers, Wisc. 53171.

AUDIBLE I.D. TIMER KIT, P.C. board, instructions, less batt. & case, $8.50 ppd. J. Isenagle, Box 636, Port Hueneme, CA. 93041.

RTTY TERMINAL UNIT: PLL decoder, AFSK generator, loop supply, handsome cabinet, wired and tested, $169.95. Save, separate boards & kits available. Com Tech Electronics, P. O. Box 73, Rensselaer, N. Y. 12144.

B&K TEST EQUIPMENT. 15% discount. Free shipping. Free catalog. Spacetron, Box 84D, Broadview, IL 60153.

WANTED: Old radio show transcription discs, any size, any speed. Also wire recordings. Billy Stricklin, 118 Coburn Drive, Chattanooga, Tenn. 37415.

TS520, NEVER USED with CW filter and external VFO. AC only, $675. Heath SB300/401 combo with VFO switching, all filters, Heath desk microphone mint $400. Linear $175. W6TC, 415-584-4649.

TRAVEL-PAK QSL KIT — Send call and 25¢; receive your call sample kit in return. Samco, Box 203, Wynantskill, N. Y. 12198.

DIRECT CONVERSION RECEIVER KITS for AM or CW. Write WB9MBH, 3132 North Lowell Avenue, Chicago, Illinois 60641.

FREE Electronics Surplus Catalog. Electronic Specialties, 1659 Wetmore, Tucson, AZ 85705.

TOUCH TONE PADS, used A.E. $5.00 each. Sam Cowan, WØOAJ, Box 118, Elmwood, NE. 68349.

NEW CANADIAN MAGAZINE. "Electronics Work Shop". $5.00 yearly, sample $1.00. ETCOB, Box 741, Montreal, H3C 2V2.

flea market

COLLINS R-390, $375. Excellent operating condition and appearance, lab checked, with manual. B. Rowan, 55 Runnymeade Road, Berkeley Heights, N. J. 07922. (201) 464-5090.

WANTED: Heath HW-100 with AC supply and a 3 to 10 element 10 meter beam in good condition. WAØRIO, George Peck, Jr., P. O. Box 243, Caldwell, KS 67022.

FOR SALE: Genave GTX-200T, factory tone pad, 4 channels, mint condx. $240. Heathkit SB-102 A-1 shape, make offer. WAØNZQ, Curtis R. Olson, P. O. Box 215, Regent, N. Dak. 58650.

MANUALS for most ham gear made 1940/65, some earlier. Send SASE for specific quote. Hobby Industry, WØJJK, Box H-864, Council Bluffs, Iowa 51501.

MODERN 60 MIN. CODE CASSETTES. Novice 0-5 wpm, Progressive 5-13 wpm, General 13-15 wpm, Extra 20-22 wpm. $3 each, 4/$10. Royal, Box 2174, Sandusky, Ohio 44870.

ANTIQUES: Meters, 10 MA to 500 MA, $3.00 each; Cardwell & National Variables, $2.00 each; ARRL License Manual, 2nd Edition, $2.00; B & W plug-in coil set, TVL, $10.00; ARC 5 receiver, 50 KC, $10.00; Tubes, 1920 to 1940 SASE for list. W2LWO, #311 48 States Park, Pleasantville, N. J.

QRP TRANSMATCH for HW7, Ten-Tec, and others. Send stamp for details to Peter Meacham Associates, 19 Loretta Road, Waltham, Mass. 02154.

WANTED: May 1975 Ham Radio magazine. Advise price, MO will follow. W6WJC, Ken, 536 West Hillsdale, Inglewood, Calif. 90302.

MOBILE IGNITION SHIELDING provides more range with no noise. Available most engines. Many other suppression accessories. Literature, Estes Engineering, 930 Marine Dr., Port Angeles, WA 93862.

VHF TRANSCEIVERS FOR SALE. Knight TR106 six meters $65. TR108 two meters $70. W8TYX, 614-268-7797.

SIDESWIPER only $13. Airmailed USA. Kungsimport, Box 257, Kungsbacka, Sweden.

ALTAIR 8800 OWNERS, add output registers with LED displays at few dollars. For complete, easy-to-build plans; checkout program; and demonstration, computer-game program; forward $5.00 (postpaid continental U.S.) to Computer Research, Inc., 1600 Pennwood Drive, Hampton, Va. 23666. Satisfaction Guaranteed.

MOTOROLA HT220, HT200, Pageboy, and other popular 2M FM transceiver (Standard, Regency, etc.) service and modifications performed at reasonable rates. WA4FRV, (804) 272-8403.

DEFLECTION YOKES — For 1" Vidicon with transistor deflection circuits. New precision yokes, $10.00 each while they last. Add 50¢ each for shipping. Aptron Laboratories, P. O. Box 323, Bloomington, IN. 47401.

SILVER MICAS, one percent, short leads, pulls from boards. 6 assorted values for $1. KP4OSD, Box 297, Sabana Seca, P.R. 00749.

MANUALS for Govt. surplus gear, $6.50 each: URM-25D, SP-600JX, TT-63A/FGC, TS-497B/URR, TS-382D/U, ALR-5. Thousands more available. Send 50¢ (coin) for 22-page catalog. W3IHD, 7218 Roanne Drive, Washington, D. C. 20021.

BAZOOKA DIPOLE . . . Ready to use, with fiberglass center SO239, end insulator 80M, $29.50; 40M, $26.50; 20-15-10M, $23.50. Fiberglass central insulator with SO239, 1000 pound test, $5.95. Trap 2 KW 80/40, 40/20, $18.50, ppd. Jac-Tenna, 13850 Victorin, Tracy, P. Que., Canada.

MANUALS for most ham gear, 1939/70. List $1.00. Send SASE (or 25¢) for one specific model quote. Hobby Industry, WØJJK, Box H864, Council Bluffs, Iowa 51501.

MOTOROLA HT220, HT200, Pageboy, and other popular 2M FM transceiver (Standard, Regency, etc.) service and modifications performed at reasonable rates. WA4FRV, (804) 272-8403 evenings.

IC APPLICATIONS MANUAL — Analog/Digital $3.95. Digital IC manual - latest edition-3000 latest types/pinout diagrams/cross references $6.95. Electronetics-HRM, P. O. Box 127, Hopedale, MA. 01747.

RADIO MUSEUM now open. Free admission. 15,000 pieces of equipment from 1850 telegraph instruments to amateur and commercial transmitters of the 1920's. Amateur station W2AN. Write for information. Antique Wireless Assn., Main St., Holcomb, N. Y. 14469.

More Details? CHECK—OFF Page 118

flea market

YAESU FT-101 OWNERS. Add Fast-Slow-No AGC easily. For complete details send dollar (creditable toward dues) for April issue of Newsletter. International Fox-Tango Club, 248 Lake Dora Drive, W. Palm Beach, FL 33411.

PC's, Send large S.A.S.E. for list. Semtronics, Rt. #3, Box 1, Bellaire, Ohio 43906.

YAESU OWNERS — Send a dollar (creditable towards dues) for June issue of widely acclaimed FT Newsletter. International Fox-Tango Club, 248 Lake Dora Drive, W. Palm Beach, FL 33411.

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

RTTY — NS-1A PLL TU (RTTY Journal 1/76) FSK/AFSK. Wired/tested $29.95 ppd. Boards, parts kits available. Stamp for info. Nat Stinnette Electronics, Tavares, FL. 32778.

FREE flyer of unusual surplus equipment and components: military, RF, semiconductors, coils, capacitors, etc. Free gift with first order. Gold Electronics Company, Dept. H, Box 1814, Rochester, NY 14603.

NAMEBADGES $1.25, name and call sign $1.75. Engraved plastic with pin or clutches. Black, white, red, blue, green, woodgrain. Include payment with order. Club emblem and hamfest badges. SASE for catalog. Donan's Engraving, P. O. Box 07155, Lakewood, Ohio 44107.

ENGRAVED RADIO LICENSE. Exact reproduction in solid brass. Permanent identification. Send good Xerox copy, with $5.00, to Metal Art Graphics, 1136 Potomac Ave., Hagerstown, Md. 21740.

EMPIRE NF 105 Field Strength Meter, 4 tuners $1100, HP-302A wave analyzer $550, Lampkin 205 deviation meter $75, HP-410B VTVM $75, Boonton 85C RF millivoltmeter/distortion analyzer $175, AN/TRM-1 signal generator .19-400 MHz $250, HP-612A signal generator $550. James Walter, 2697 Nickel, San Pablo, Ca. 94806.

VARIABLE CONDENSORS, Johnson 154-3, 19-488pF, 2 KV, used, excellent condition, $12 each or 3 for $30, postpaid. Box 297, Sabana Seca, P. R. 00749.

ADD A TOUCH OF CLASS. Mod-U-Line cabinets, ST-6 style MCP 3-17-12 gray $27.97. 500 styles available. Many other electronic parts stocked. Stamp brings info. NuData Electronics, 104 N. Emerson St., Mt. Prospect, IL 60056.

TELETYPE EQUIPMENT FOR SALE for beginners and experienced operators. RTTY machines, parts, supplies. Special beginners package consists of Model 15 page printer and TH5-TG demodulator, $125.00. Atlantic Surplus Sales, 3730 Nautilus Ave., Brooklyn, N. Y. 11224. Tel: (212) 372-0349.

TELETYPE MACHINES, Model 33, $650.00. Model 35, $2100.00, model 37, $1100.00 Perfect condition including modems for computer time share. Tony, K9HJU, 312-349-9002, after 6 p.m.

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

CIRCUIT BOARDS. Artwork, negatives, etching. SASE for details. Karl Raup, WB4OXG, Box 498, Springfield, Virginia 22150.

VHF EQUIPMENT, Clegg Venus and power supply, 6 meter SSB transceiver, $140. Interceptor 6 and 2 meter receiver, $120. Tom Hamilton, 392 W. Lincoln, Birmingham, MI. 48009.

NEW POWERFUL THREE OUTPUT Regulated Power Supply, Plus 900 parts worth $400.00 list. Solid state TV recorder electronic unit. Schematics, parts cross reference. Free brochure. $17.95 plus $3.50 S & H, USA. Master Charge, BankAmericard. Madison Electronics Company, Inc., Box 369, Madison, Al. 35758.

QSL'S — BROWNIE W3CJI — 3035B Lehigh, Allentown, Pa. 18103. Samples with cut catalog 50¢.

500 MHz PRESCALER divide by 10 or 100, input 50 ohms — 100 MV sensitivity $59.95. Plans & parts list $5.00. CBS Enterprises, P. O. Box 1356, Cocoa Beach, Florida 32931.

BUY — SELL — TRADE. Write for free mailer. Give name, address, call letters. Complete stock of major brands, new and reconditioned equipment. Call us for best deals. We buy Collins, Drake, Swan, etc. SSB & FM. Associated Radio, 8012 Conser, Overland Park, Ks. 66204. 913-381-5901.

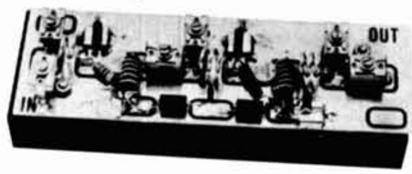
More Details? CHECK—OFF Page 118

Build a 2 meter or 220 MHz Transceiver.

10 Channel Scanning . . . 15 Watt

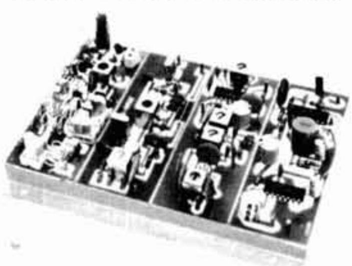
You can put it all together for only $219.95

PA144/15 - 15 Watt Power Amplifier



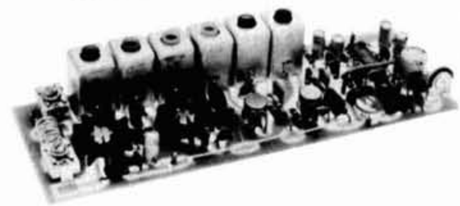
POWER GAIN; 12 db nominal, INPUT POWER; 2 watts max., INPUT VOLTAGE; 12 to 14 volts DC negative ground, INPUT CURRENT; 4 amps max., STANDBY CURRENT; virtually insignificant, INSERTION LOSS; less than 1 db on receive, DUTY CYCLE; 50% or less. Consists of drilled glass PC Board, heat sink and all components.

RX144C or RX220C Receiver Kit

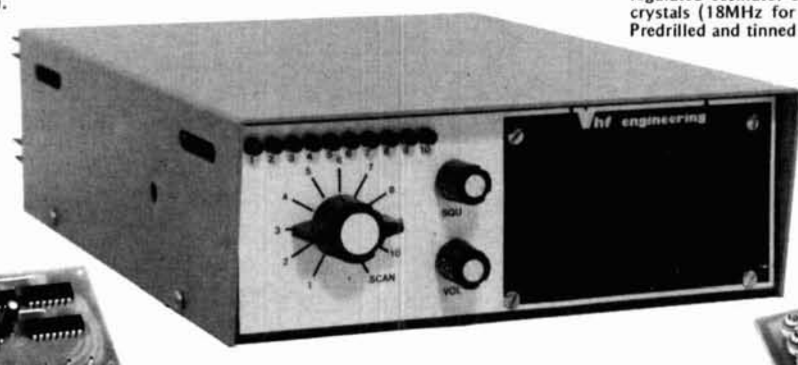


SENSITIVITY .3uV for 20db quieting. SQUELCH THRESHOLD .2uV. AUDIO OUTPUT 2 watts. STABILITY better than −.002. IMAGE REJECTION 60db. SPURIOUS REJECTION greater than 60db. IF REJECTION 80db. FIRST IF 10.7 Mhz. SECOND IF 455 Khz. BANDWIDTH 15 Khz at 3db, 60 Khz at 30db (40 Khz with optional 4 pole filter). CRYSTAL 45 Mhz parallel at 20pf (HC/25U holder).

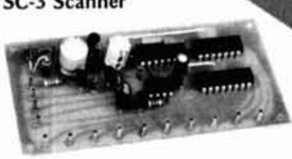
TX 144B or TX220B Transmitter Kit



A one watt exciter using four RF transistors, two diodes, and one integrated circuit. The RF transistors are operating well below their ratings allowing long keying periods without damage. • Nominal output 1½ watts • Deviation adjusted to 10KHz • IC audio with clipping and active filter • All spurious outputs down 30db or more • Temperature compensation crystal trimmer • Zener regulated oscillator • Uses readily available 12 or 18 MHz crystals (18MHz for 220) • All tuning coils prewound • Predrilled and tinned G-10 Circuit board



SC-3 Scanner



Capable of scanning up to 10 channels. Scan delay allows both sides of a conversation to be monitored without the scan starting each time the carrier drops. The priority feature allows the user to program the scanner to return to his favorite channel whenever it is active.

CD-2 Crystal Deck

Designed to provide multi-channel operation for the TX-series transmitters. It features an extra set of contacts that may be wired to the CD-1 crystal deck for 10 channel transceive. The extra contacts may also be used to switch L.E.D. indicators. The switch has 11 positions.

CD-1 Crystal Deck

A ten channel receiver crystal deck which utilizes diode switching to select the crystal position required.

Complete with cabinet, speaker, hardware, L.E.D.'s, all accessories and full assembly instructions.

(Crystals and microphone not included.)

ORDER FORM

Item	Price Each	Quantity	Total Price
Transceiver TRX 144 Kit	$219.95		
Transceiver TRX 220 Kit	$219.95		

Name ______ Total ______

Address ______ Shipping ______

City ______ NYS Resident Sales Tax ______

State ______ Zip ______ Total Enclosed ______

Master Charge or BankAmericard No. ______

Bank No. ______ Expiration Date ______

SHIPPING INFORMATION: All shipments are F.O.B. Binghamton, N.Y. 13902. Shipments will be made by the most convenient method. Please include sufficient funds to cover shipping and handling. Figure shipping charges on a weight of 6 pounds. Allow 3 to 4 weeks for delivery.

TERMS: C.O.D., cash or check with order. We also accept BankAmericard and Master Charge.

CLAIMS: Notify VHF *and* the carrier of damage within seven (7) days of receipt of shipment.

RETURNS: Obtain authorization from VHF before returning *any* merchandise.

PRICES AND SPECIFICATIONS: Subject to change without notice.

Export prices are slightly higher.

THE WORLD'S MOST COMPLETE LINE OF VHF - FM KITS AND EQUIPMENT

Vhf engineering

DIVISION OF BROWNIAN ELECTRONICS CORP.

320 WATER ST. • P.O. BOX 1921
BINGHAMTON, N.Y. 13902 • 607-723-9574

WE HONOR master charge THE INTERBANK CARD — BANKAMERICARD

More Details? CHECK—OFF Page 118

flea market

PC BOARD negatives made photographically from your magazine's artwork. Now obtain professional results quickly, simply. 4 x 5, $3.00 or SASE for information. WA4FRV, 10139 Apache Road, Richmond, Virginia 23235. 804-272-8403.

NEED HELP holding your PC board while you solder the components? My fixture will sit on your kitchen table and adjusts to fit PC boards up to 6¾" wide (length unlimited). Order now. Only $7.95 ppd in USA (Mo. residents add 25¢). W. N. Wellman Co., Box 722A, 451 Saline Rd., Fenton, Mo. 63026.

EXCLUSIVELY HAM TELETYPE 21st year, RTTY Journal, articles, news, DX, VHF, classified ads. Sample 35¢. $3.50 per year. Box 837, Royal Oak, Michigan 48068.

OSCAR 7, SSB-CW TRANSMIT CONVERTERS. For 28 or 50 MHz input at 20 mw. 432 MHz output at 1 watt. Solid state, for 12 volt supply. 35 watt solid state amplifier available for this converter. Units designed and built by WØENC. Write for information. UHF-VHF Communications, 53 St. Andrew, Rapid City, S. D. 57701.

Coming Events

QSO PARTY. Amateurs the world over are invited to take part in the 17th Annual New Jersey QSO Party sponsored by the Englewood Amateur Radio Association. Saturday, August 21 and Sunday, August 22. Send SASE to Englewood Amateur Radio Association, Inc., 303 Tenafly Road, Englewood, NJ 07631 for rules.

MISSOURI: Antique Aircraft and Amateur Radio Show, July 24 and 25, 1976. Slater Memorial Airport. Registration $1.00 in advance: $1.50 at the door. Buffalo burger feed Saturday night and Sunday noon. Talk-in 3963 kHz, 146.94 and 146.28/.88. Information, advance tickets, Dale Beilsmith, WØKNF, 807 North Broadway, Slater, Missouri 65349, (816) 529-2173.

MEMPHIS IS BEAUTIFUL IN OCTOBER! The Memphis Hamfest, bigger and better than the 3,500 who attended last year, will be held at State Technical Institute, Interstate 40 at Macon Road, on Saturday and Sunday, October 2 and 3. Demonstrations, displays, MARS meetings, flea market, ladies' flea market, too! Hospitality room, informal dinners, XYL entertainment, many outstanding prizes. Dealers and distributors welcome, too! Contact Harry Simpson, W4SCF, Box 27015, Memphis, TN 38127, phone 901 358-5707.

AMERICAN-TASMANIAN CONTEST to celebrate America's Bicentennial. Amateurs in all U.S. call areas to contact amateurs in the VK7 (Tasmania) call area from 1400 hours GMT, 3rd July to 1400 hours GMT, 4th July. There shall be two (2) sections. Single band, transmitting open and multi band, transmitting open (both single operator). Stations may be fixed, portable or mobile. All modes and cross mode contacts are permitted. All amateur bands may be used but cross band contacts are not permitted. All logs and questions to Contest Manager, P. O. Box 1010 Launceston Tasmania 7250, Australia before 1st November 1976.

OWOSSO, MICHIGAN Buzzards Roost and Emergency Nets Picnic and SARA Swap and Shop at Mc Crudy Park, Corunna, Michigan. Early bird get together Saturday evening, July 17. Swap and Shop, picnic on Sunday, 8 a.m.-5 p.m., July 18. Free admission, tables for swap and shop $2.00, tickets available for drawings, overnight trailer & camping space available. Talk-in on 3930 kHz, 146.52 MHz with repeaters on 147.63/.03 and 449.30/442.10 MHz. For further information, write SARA, 1302 W. Main St., Owosso, Mich. 48867.

SPECIAL "VIKING" LANDING COMMEMORATIVE. Jet Propulsion Laboratory Amateur Radio Club (JPL-ARC) will be making contacts with amateurs all over the U.S. and many foreign countries in conjunction with the bicentennial project of landing on Mars. JPL-ARC will be active "on the air" with a special commemorative program during the Mars encounter by the Viking I and Viking II spacecraft using the special call of N6V, operating from Pasadena, Calif. Will operate on the following approximate frequencies: CW — 3530, 7030, 14030, 21030, 28030, kHz. SSB — 3810, 3930, 7230, 14225, 14325, 21360, 28630 kHz. Novice CW — 3730, 7130, 21130, 28130 kHz. Exact time/dates of operation not yet determined as they are dependent on Viking spacecraft schedules. Closest approximation is: June 18 to 23, July 3 to 18, Aug. 6 to 12, Aug. 31 to Sept. 15. Viking status reports may be secured by calling (213) 354-4213.

More Details? CHECK—OFF Page 118

flea market

RADIO EXPO '76, September 18, 19, near Chicago. Exhibits, seminars, giant flea market open Friday night. Campers welcome. Advance ticket $1.50. Box 1014, Arlington Heights, Ill. 60006.

MELBOURNE, FL., SEPT. 11-12. The 11th Annual Melbourne, Florida Hamfest will be held Saturday and Sunday, September 11-12, 1976, from 9 a.m. to 5 p.m. each day in the air conditioned Melbourne Civic Auditorium located on Hibiscus Boulevard. Donation is $2.50 per adult. Full program includes forums, meetings, auction, swap tables, commercial exhibits, awards, prizes, etc. Talk in on 25/85 and 52/52. Sponsored by Platinum Coast Amateur Radio Society. For more info write P. O. Box 1004, Melbourne, FL 32901.

KENTUCKY. Lake Cumberland A.R.C. Hamfest Sunday, July 11, 1976, 10:00 a.m. 'til, Somerset's Outdoorsmen's Club, Somerset, KY.

DANVILLE HAMFEST at Douglas Park, Danville, Ill. Sept. 5. Downstate Illinois' largest. Great prizes. Advance tickets $1.75 ea., 3/$5 with SASE to Jim Wilson, 308 First, Ridgefarm, IL. 61870. Talk-in 22/82, 3910.

PITTSBURG, KANSAS REPEATER ORGANIZATION hamfest and watermelon feed, Sunday, July 25, 1976 at the Lincoln Park shelters in Pittsburg, at the 10th Street and Bypass 69 intersection. There will be a covered-dish picnic, transmitter hunts, swap meet, and lots of prizes including many for the YL's and harmonics. Talk-in will be on WRØADZ 34/94 and 52/52.

WESTERN PENNSYLVANIA — The 39th Annual Hamfest of the South Hills Brass Pounders and Modulators will be held on August 1st, from noon til dusk, at St. Clair Beach, Upper St. Clair Township, 5 miles south of Mt. Lebanon, on Route 19. Swap and shop, picnic space and swimming. Talk in on 29.0 and 146.52. Information and pre-registration at $1.50 per ticket ($2.00 at door) from K3FIW, 181 County Line Road, Bridgeville, Pa. 15017. Vendors must register.

PENNSYLVANIA Skyview Radio Society's Swap & Shop will be held on Sept. 19, 1976 at Skyview Radio Club, New Kensington, Pa. Registration $1. Check ins on 52-52 and 04-64.

WARREN, OHIO HAMFEST, August 22, 1976, moved to Trumbull Expo Center, north of city; bigger flea market, plenty of close-in parking. Displays, talk-ins, $2 door prize registration. Family recreation, state park nearby. Arrow signs lead from Interstates 80, 90, Ohio Rtes. 5, 11, 305. Details? QSL: WARA, Box 809, Warren, Ohio 44482.

NORTH ALABAMA HAMFEST — Sunday, August 15 at The Mall in Huntsville, Ala. Hamfest supper on Saturday night. Prizes, flea market, and displays. ARRL forum, MARS meetings, and XYL programs. Talk-in on 146.94 and 3965. For more information: N.A.H.A., P. O. Box 423, Huntsville, AL 35804.

THE OKLAHOMA HAM HOLIDAY and State ARRL Convention will be held Saturday and Sunday, August 7 and 8 in Oklahoma City, Oklahoma. The largest flea market in the Southwest, special programs, technical seminars, equipment displays, and activities for the ladies. For information and advance registration write Oklahoma Ham Holiday, Box 20567, Oklahoma City, Oklahoma 73120.

BICENTENNIAL SPECIAL EVENTS STATION (NSØDAK) operated by the Black Hills A.R.C. at Mt. Rushmore National Memorial (in the Black Hills of South Dakota). July 3, 4, & 5. SSB and CW on general and advanced portions of 80-10 M and 2 M FM. Special QSL cards available. QSL with SASE to KØCXL, 715 San Marco, Rapid City, SD 57701. Authorization good through September 6. Watch for us on other weekends and holilays.

13TH ANNUAL INTERNATIONAL HAMFEST will be held July 10 and 11, 1976 at the International Peace Garden between Dunseith, North Dakota and Boissevain, Manitoba. This year it will be held in the Canadian Pavilion. Excellent camping, contests, prizes, party & dance, Sunday breakfast, and meetings. For more info contact WBØGFZ or VE4OD.

NEW JERSEY: The 550 Amateur Radio Club and Oakland Repeater Association annual Hamfest/Picnic, Westbrook Park Kampgrounds, West Milford, N. J., July 31 and August 1. All amateurs, their families and guests are invited. Talk in via club repeater WR2AHD 147.49 MHz/146.49 MHz and 223.34 MHz/224.94 MHz. For additional information, contact WA2HLE, 73 Page Drive, Oakland, N. J. 07436. Phone: (201) 337-0316.

ARIZONA: Ft. Tuthill Hamfest, July 30-31 and August 1 at Flagstaff, Arizona (Coconino County Fair Ground - Across I-17 from Airport). R-V and tent camping. Three days in the tall cool pines. Swap meet, tech sessions, contests, prizes, pot luck, exhibits. Talk in 146.22/82, 146.34/94, 146.52 and 3992 kHz.

ZERO-BEATERS ARC hamfest, Sunday, August 1, at Washington, Mo. city park. Free parking, auction, bingo for XYL's. No admission fee, no fee for traders row. Many prizes. Info or tickets, Al Lanwermeyer, WNØQBS, or Zero-Beaters ARC, WAØFYA, Box 24, Dutzow, Mo. 63342.

STRAITS AREA RADIO CLUB Swap and Shop, 8:00-4:00, Aug. 14, 1976 at Emmet County fairgrounds on US 31, ½ mile west of southern junction of US 31 and US 131, in Petoskey, Michigan. All amateurs, CBrs, SWLs, $1.00 admission, 50¢ per table, door prizes, lunch counter, free parking. Talk-in on 3.920 MHz., Channel 1, 146.52 MHz.

MINNESOTA: St. Cloud Radio Club Hamfest, August 8, 1976, 10:00 a.m. till closing, at the Sauk Rapids Municipal Park. Free parking and overnite parking. Hot dogs and pop available. Swapfest and ham gear sale. Talk in on 34/94 and 3925. Hope to see you all there. For further info. contact Bill Zins, WAØOTO, St. Cloud Radio Club, P. O. Box 752, St. Cloud, MN. 56301.

SHANGRI-LA '76 — ARRL Hudson Division Convention, November 13-14. Great Gorge Resort Hotel, McAfee, New Jersey. Exhibits, flea market, FCC and ARRL forums, Special YL programs, technical sessions and a Saturday night banquet with Jean Shepherd, K2ORS, world traveler, columnist and famed radio personality of WOR. For information write to Al Peddington, WA2FAK, 4 Acorn Drive, East Northport, N. Y. 11733.

THE ANNUAL FORT WAYNE Repeater Association FM Picnic will be held at the Steuben County Fair Grounds, near Angola, Indiana on August 1, 1976. Flea market, special events, and fun and prizes. $1.50 for all, unless you are under 12 years of age. All in frequencies are .16-.76, .28-.88, .52 and .94.

Stolen Equipment

GENAVE GTX 200, SN22-03, SS number 031-28-9354. BNC on back for duplex operation. Early vintage set. Stolen from Gus McKinney, WBØOPR, 303-473-1397, 807 Holmes Drive, Colorado Springs, Colo. 80909.

REGENCY HR2A, SN04-10422. Has bracket attached and cigarette lighter plug on power cord. Stolen from: Don Billings, WØGOH, 303-636-1661, 2838 N. Prospect St., Colorado Springs, Colo. 80907.

REGENCY HR2B, SN unknown. Stolen from: Glenda Butler, WBØOCH, 303-544-7777, 1509 E. 12th St., Pueblo, Colo. 81001.

MOTOROLA TWO FREQ., control head, Motorola T-power mike, Moto. speaker, 16 button TT pad with light, mounted in Bud box. Stolen from: Jim Best, WAØRZI, 303-471-1486, 1923 Alpine Drive, Colorado Springs, Colo. 80907.

REGENCY HR2, SN unknown. Owners name inside. Stolen from, Dwane Barber, WAØWWO, 303-352-4711, RFD 3, Box 353, Greeley, Colo. 80631.

EBC 144JR. SN 50108, synthesized rig. Stolen from: Dick Sucher, WAØZLY, 303-471-1696, 27 Leaming Rd., Colorado Springs, Colo. 80906.

ICOM IC22A, SN3401802. Call engraved on back, accessory plug wired for TT, PTT, and 455KC output. Stolen from: Bill Croghan, WBØKSW, 303-471-7504, 1030 W. Colorado, Colorado Springs, Colo. 80905.

HEATH HW 202, Series 00316 Transceiver. Modified: BNC antenna connector, scanner w/LEDs over top (extra) barswitch. 3 switches to left not connected. Right switch turns scanner off/on. Wires were cut at back panel. Stolen from: Dick Ellis, W5YCK, 104 West Ave. A., Alpine, TX 79830. Phone: 915-837-3728.

REGENCY HR-2A, SN04-07989. Chassis engraved K3NVO, 495-38-8556. Has scanner board mounted over rcv xtals and 4 red LEDs mounted vertically on front panel for channels 1-4. Stolen from: Ronald Kaullen, 6326 Blue Flag Ave., Harrisburg, PA 17112.

GENAVE GTX-1T Handheld Transceiver, SN 13-07. Stolen from: Genave's display booth at Dayton Hamvention. Contact Genave, 4141 Kingman Dr., Indianapolis 46226.

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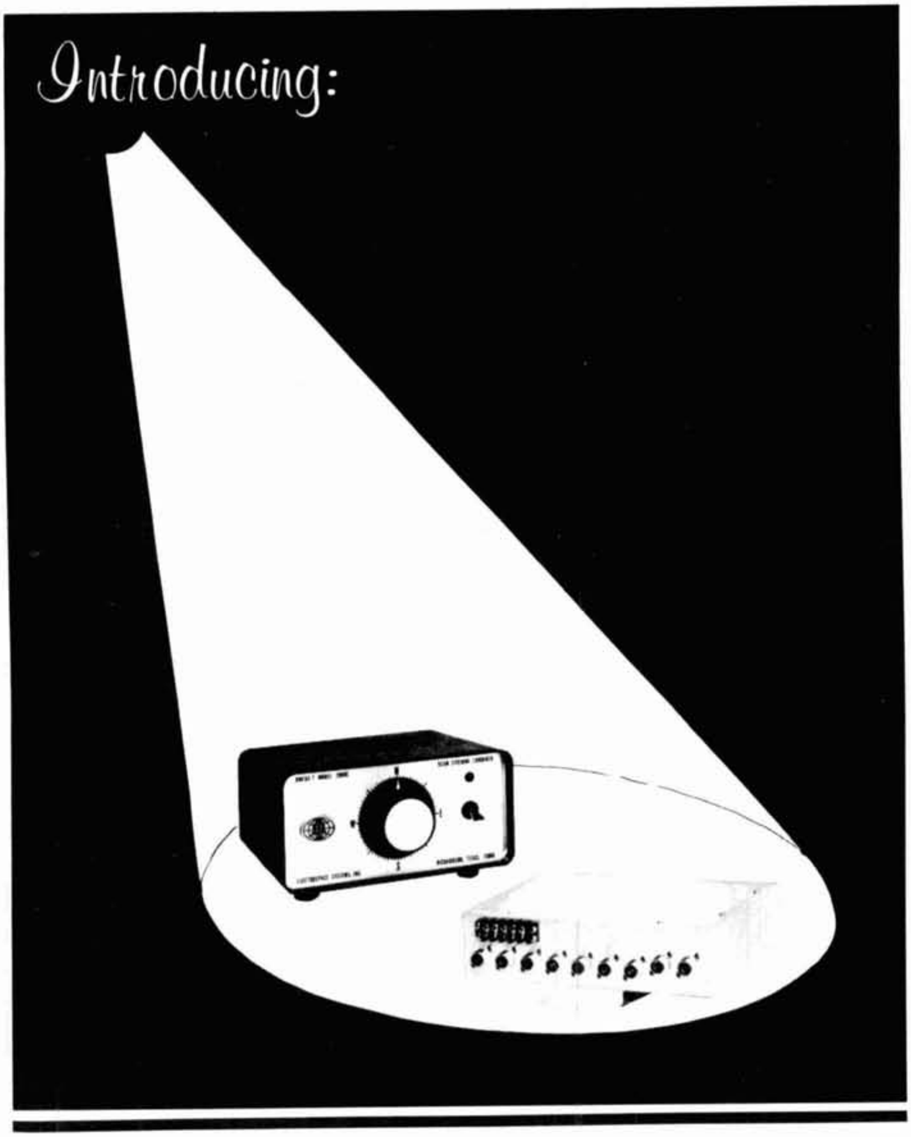

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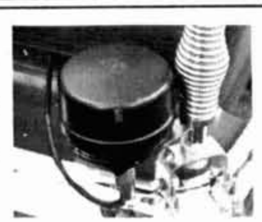

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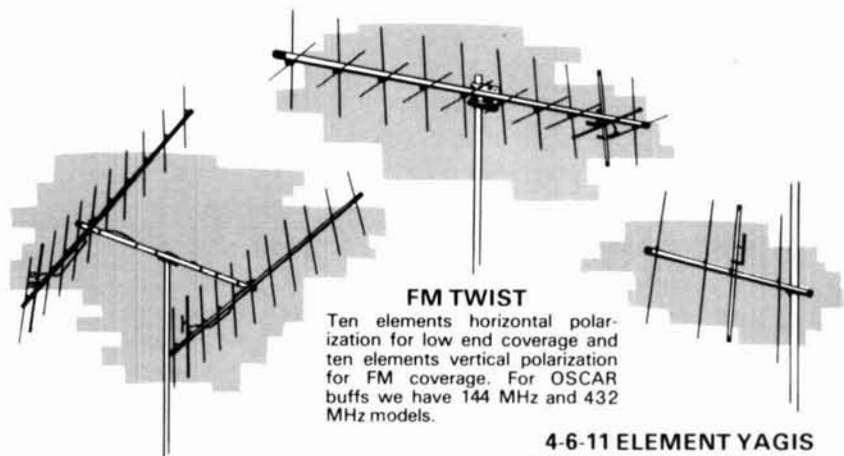

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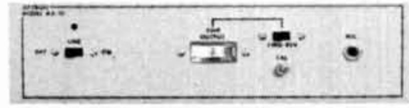

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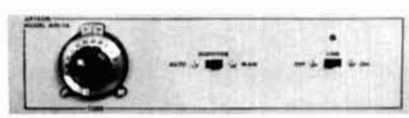

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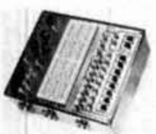

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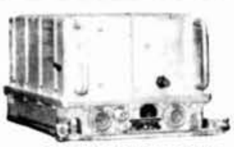

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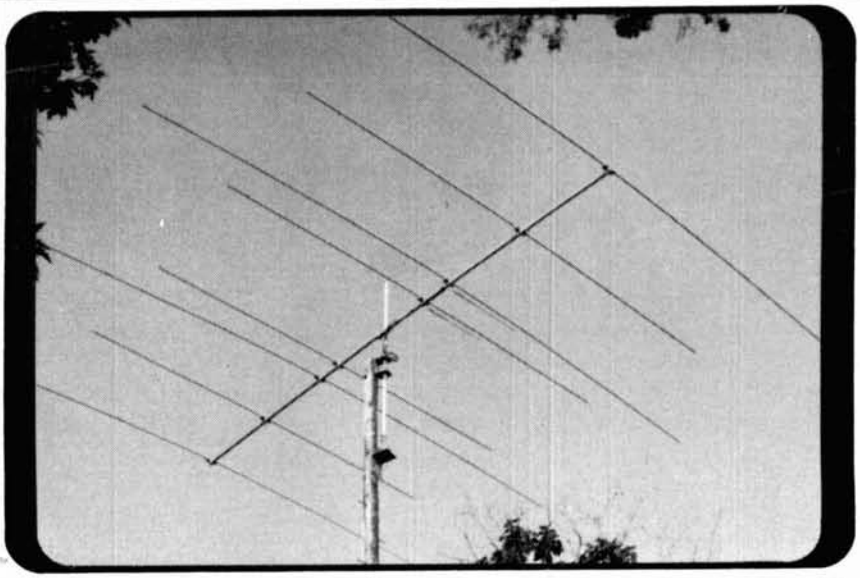

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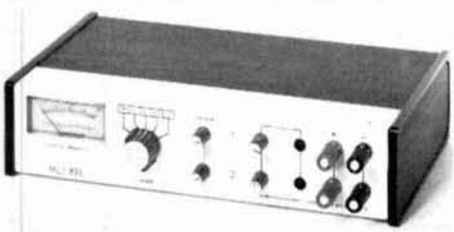

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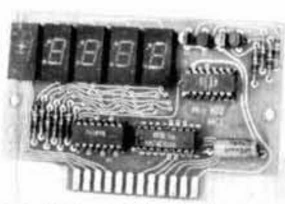

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NEW

SUPER LOGARITHMIC SPEECH PROCESSOR

Up To 400% More RF Power is yours with this plug-in unit. Simply plug the LSP-520BX into the circuit between your microphone and transmitter and your voice suddenly is transformed from a whisper to a **Dynamic Output.**

Look what happens to the RF power output on our NCX-3. It was tuned for normal SSB operation and then left untouched for these "before" and "after" oscillograms.

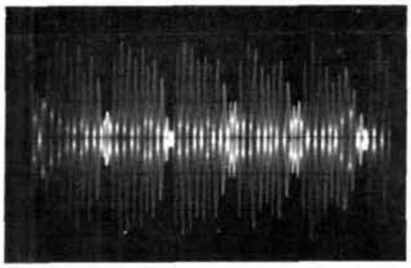


Fig. 1. SSB signal before processing. See the high peaks and the low valleys. Our NCX-3 is putting out only 25 watts average power.

Fig. 2. SSB signal after processing with LSP-520BX. The once weak valleys are now strong peaks. Our NCX-3 now puts out 100 watts of average power.

Three active filters concentrate power on those frequencies that yield maximum intelligence. Adds strength in weak valleys of normal speech patterns. This is accomplished through use of an IC logarithmic amplifier with a dynamic range of 30 db for clean audio with **minimum distortion.**

This unit is practically distortion-free and produces **crisp, clear audio** even at 30 db compression! The input to the LSP-520BX is completely filtered for RF protection. A 9 volt transistor battery provides months of operation. Standard 3 conductor quarter inch phone jacks are used for input and output. 3-3/16 x 3-1/4 x 4 inches.

LSP-520BX, assembled	$49.95
LSP-520BX II, assembled	$59.95
LSP-520PC, wired PC board	$37.95

The LSP-520BX II includes all the features of the LSP-520BX and, in addition, includes an uncommitted 4 pin mic jack, a rotary function switch, an output mic cable and a beautiful Ten-Tec enclosure, 2-1/8 x 3-5/8 x 5-9/16 inches.

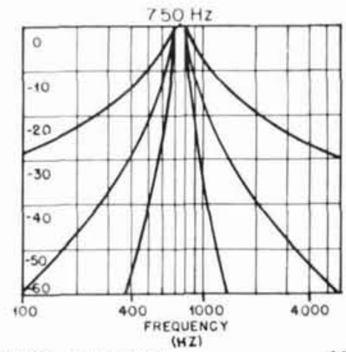
IMPROVED

CW FILTER

The **Original** high performance, non-ringing CW filter, CWF-2BX, is by far the leader. **Over 5000 In Use.** You get **razor sharp** selectivity from its **80 Hz Bandwidth** and extremely steep sided skirts (see response curves). Even the weakest and most battered signal stand out.

Plugs into **any** receiver or transceiver. Drives phones or connect between receiver audio stage for speaker operation.

• No ringing • Bandwidth: 80 Hz, 110 Hz, 180 Hz (selectable) • Skirt rejection: at least 60 db down one octave from center frequency for 80 Hz bandwidth • Center frequency: 750 Hz • Drastically reduces all background noise (up to 15 db improvement in S/N ratio) • Provides gain • No impedance matching • 8 pole active filter uses ICs • 9 volt transistor battery provides months of operation • 400 Hz or 1000 Hz center frequency optional. Add $3.00 • Size: 3-3/16 x 3-1/4 x 4 inches.



CWF-2BX, assembled	$27.95
CWF-2P, wired PC board	$18.95
CWF-2PCK, kit PC board	$15.95

WARRANTY

All products manufactured by MFJ Enterprises are **UNCONDITIONALLY GUARANTEED** for a period of one year from the date of purchase. This means we will repair or replace free of charge any of our products which are defective for any reason.

MFJ Enterprises

P. O. BOX 494(H)
MISSISSIPPI STATE
MISSISSIPPI 39762
601-323-5869

NEW

CMOS ELECTRONIC KEYER

THE BEST KEYER BUY IN THE WORLD BAR NONE!

• State of the art design uses CURTIS-8043 keyer-on-a-chip • Built in key with adjustable contact travel • Dot memory • Iambic operation with external squeeze key • Instant start with keyed time base • Self completing dots and dashes • Jam proof spacing • Variable weight control • 8 to 50 WPM • Sidetone and speaker with adjustable volume and tone • Ultra reliable solid state keying: gridblock —300 V max, 10 ma. max; cathode and solid state transmitter, +300 V max, 200 ma. max. • Phono jacks for external key and keying outputs • 4 position switch for TUNE, OFF, ON, SIDETONE OFF • Completely self contained for portability • Uses 4 penlight cells (not included) • Size: 3-3/16 x 3-1/4 x 4 inches.

CMOS-8043, assembled	$39.95
CMOS-8043PC, wired PC board	$24.95

FREE CATALOG AVAILABLE.
DEALER INQUIRIES INVITED.

Date________

Qty.	Model #	Item Description	Amount

Please add $2.00 Shipping and Handling per item

Shipping and handling ______
Total Enclosed ______

☐ I enclose ☐ Check ☐ Money Order ☐ Cash in the amount of $______

☐ Please charge to my ☐ Master Charge ☐ BankAmericard Exp. Date______ No.______

☐ Send COD (please add 85¢ COD fee)

SHIP TO:

NAME______

STREET______

CITY______

STATE______ ZIP______

Signature______

"ORDER TODAY — MONEY BACK IF NOT DELIGHTED!"

More Details? CHECK—OFF Page 118

More Details? CHECK—OFF Page 118

FRG-7 COMMUNICATIONS RECEIVER

SYNTHESIZED
ALL SOLID STATE
HI-PERFORMANCE GENERAL COVERAGE RECEIVER

The Model FRG-7 is a precision-built communications receiver with continuous coverage (500 kHz to 29.99 MHz) featuring:

- Drift Canceling Circuit
- RF Attenuator
- Noise Suppression Circuit
- 5 kHz Direct Dial Readout
- Ceramic IF Filters
- AC-DC or Internal Battery
- Hi Sensitivity
- Excellent Stability
- USB/LSB/AM/CW
- Triple Conversion

Completely Solid State Circuitry for Stable Trouble-Free Operation ■ Built-in Front Mounted Speaker ■ RF Attenuator for Reception of Local or High Powered Stations ■ Outstanding Frequency Stability through the use of Drift Cancellation Circuit (Wadley Loop) ■ Recording Output Jack provides Constant Output Level Regardless of Audio Volume Control Settings ■ 3-Position Audio Range Selector 1. Normal (Broad) 2. Narrow (Hi & Low Cut Off) 3. Low (Hi Cut Off) ■ Excellent IF Receiver for VHF/UHF Converters.

YAESU
The radio.

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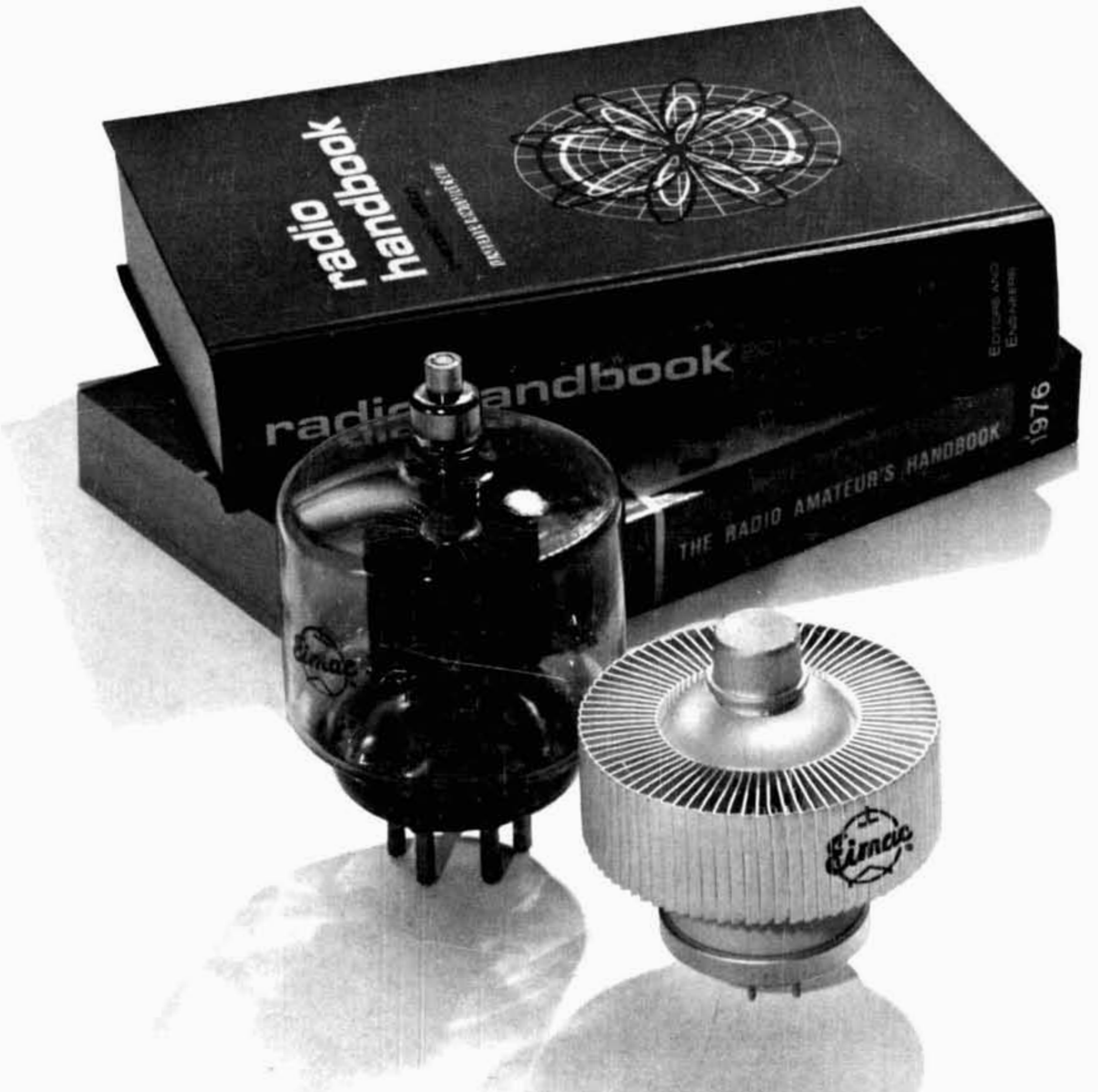
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