

one dollar

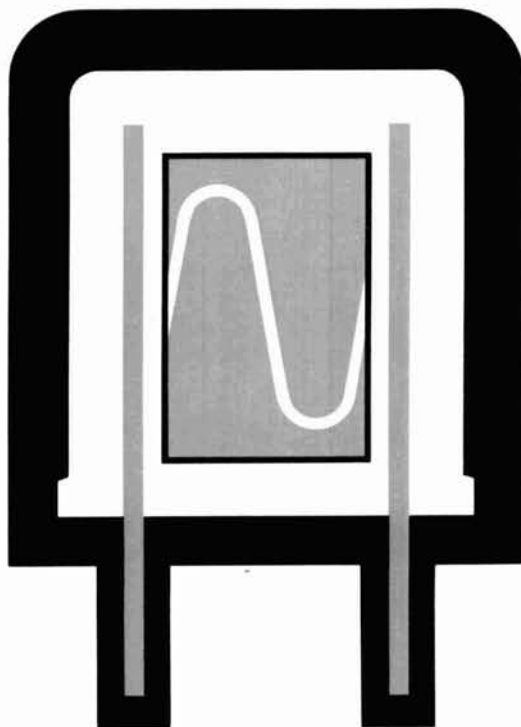
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ham **radio**

magazine

MARCH 1976

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- and much more . . .



survey of
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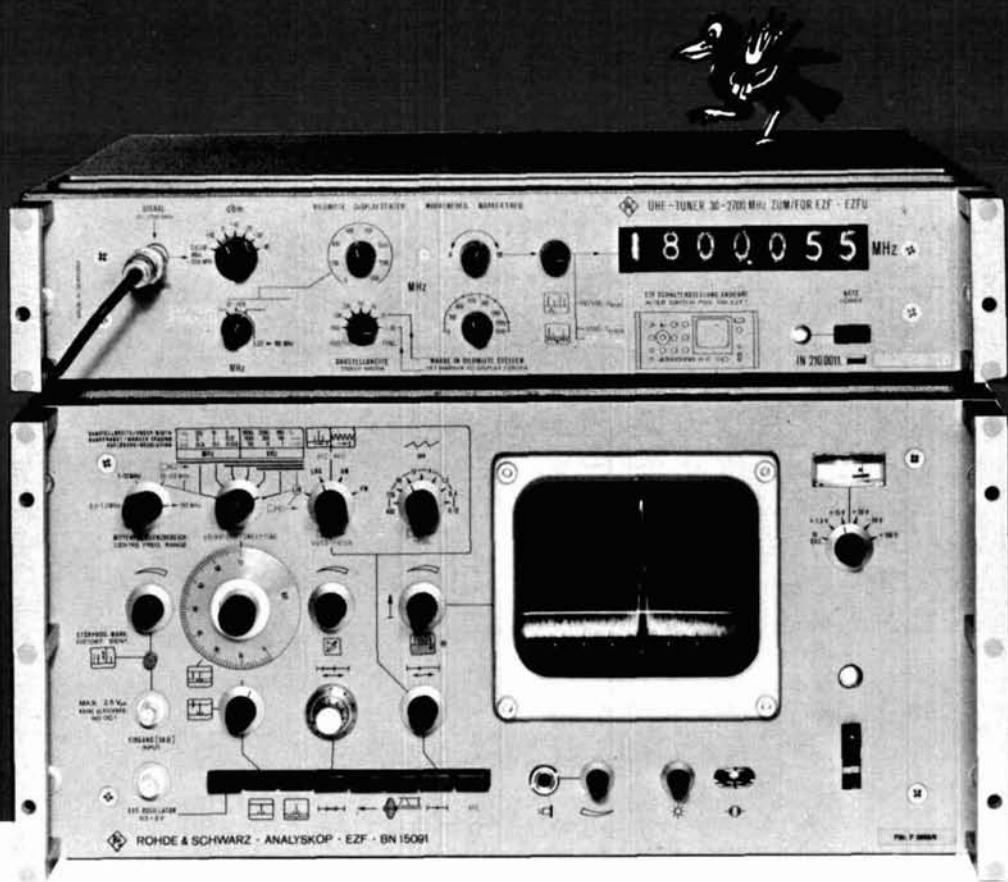
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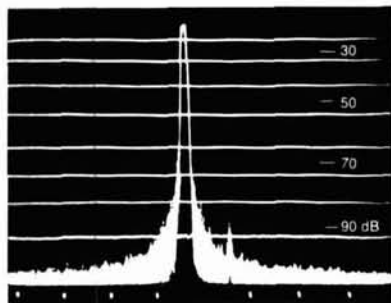


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The HAL ST-6000 demodulator/keyer and the DS-3000 and DS-4000 KSR/RO series of communications terminals are designed to give you superlative TTY performance today—and in the future. DS series terminals, for example, are re-programmable, assuring you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

The HAL ST-6000 operates at standard shifts of 850, 425, and 170 Hz. The tone keyer is crystal-controlled. Loop supply is internal. Active filters allow flexibility in estab-

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of codes, including Baudot, ASCII and Morse. The powerful, programmable 8080A microprocessor is included in the circuitry to assure maximum flexibility for your present needs—and for the future. The KSR models offer you full editing capability. The video display is a convenient 16-line format, of 72 characters per line.

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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ham radio

magazine

MARCH 1976
volume 9, number 3

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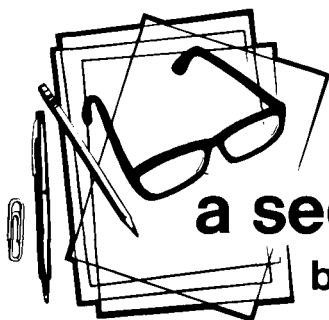
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a second look

by Jim Fisk

Recently there has been increased interest in the work of Nikola Tesla, one of the most remarkable inventors of all time, and a man who has rightfully been called the “father of radio” by some of his contemporaries. Born in Yugoslavia 120 years ago, Tesla arrived in America in 1884 with only four cents in his pocket and a letter of introduction to Thomas Edison. Edison immediately put the new immigrant to work in his New York laboratories, but the methods and temperament of the two men were fundamentally different, and the arrangement lasted less than a year. Tesla was a lone wolf, secretive, tried nothing which he had not previously thought out to the last detail, and believed that alternating current was the electrical power of the future. Edison, on the other hand, preferred to work by trial and error and was totally committed to the direct current which powered the incandescent lamps which he invented and his company lighted.

After leaving Edison’s employ Tesla worked as a common laborer — the only job he could get — but his fortunes changed in 1887 when he persuaded some financiers to underwrite his own Manhattan laboratory. His multiphase ac machinery, the designs for which he had been carrying around in his head for five years, was built, tested, and patented before the end of the year. George Westinghouse, Edison’s competitor, reportedly paid Tesla a million dollars for the patents, but after Tesla’s death in 1943 a personal friend said that Tesla actually got only \$200,000, and two-thirds of that went to his financial backers. Considering that practically all modern alternating-current machinery — generators, motors, converters, regulators and transformers — are based on early Tesla patents, the price was a pittance.

Tesla’s best known invention is probably the Tesla coil, the high-frequency, air-core oscillation transformer which is still used in laboratories to demonstrate high-voltage phenomenon. The largest of these, which Tesla built in Colorado in 1899, was used to light 200 50-watt lamps at a distance of 26 miles without any connecting wires. Convinced of the possibility of wireless power transmission, Tesla began construction of his first demonstration plant on Long Island in 1904. Shortly after the massive, 187-foot octagonal tower was completed, however, he ran out of money and was forced to abandon the project. Since Tesla never revealed how large an area he intended to cover and he kept few notes, little is known about the installation. However, this and other of his works are receiving renewed interest from modern energy researchers.

Not so well known are Tesla’s many inventions in the fields of lighting, turbine engineering, automation, high-frequency alternators, Xray apparatus, induction heating, and radio communications. One of his neglected inventions, still unused, was a carbon-button lamp which gave twenty times more light, for the same amount of current, as Edison’s incandescent filament lamp. He also described a system for detecting ships and other distant objects by aiming a powerful beam of short-wave impulses at them and picking up reflections on a fluorescent screen — a clear prophesy of the radar of the future.

Tesla first started working with high-frequency energy in the late 1880s, and at a lecture in 1892 he demonstrated wireless communications circuits which contained all the basic elements of those adopted several years later by Marconi and others. These circuits remained the same for all radio communications until the introduction of the transmitting electron tube nearly three decades later.

Believing that point-to-point communications was an obvious application of Hertz’s own 1887 experiments, Tesla made no attempt to patent his very early wireless apparatus. He was primarily interested in developing a new and efficient method of wireless power transmission, and although he was never completely successful, he developed and patented some of the most advanced wireless apparatus of the day, apparatus which was eagerly adapted by others for more profitable purposes.

In 1915 Tesla sued Marconi for infringement of his patent rights. In the long and drawn out court battle that followed Tesla became more and more of a recluse, poverty stricken, moving from one hotel to another when he wasn’t able to pay his bills. Ironically, shortly after his death the Supreme Court finally declared that Marconi’s four-circuit wireless patent (his most important) was invalid — it was predated by the work of Tesla, John Stone, and Oliver Lodge. Both Stone and Lodge acknowledged that their inventions had been inspired by the *earlier* lectures of Tesla. Perhaps on this 120th anniversary of his birth Tesla will begin to receive some of the recognition he deserves — without his genius we would all be the poorer.

Jim Fisk, W1DTY
editor-in-chief



the little surprise

The **IC-22A** has caused some pretty big surprises since it first started making waves in VHF-FM. Veteran operators have been delightfully surprised by its sophisticated styling and ease of operation; FM beginners, by its versatility, large number of possible channels, and its great value as a starter unit for FM transceiving; and all owners, by its unexcelled high quality construction and low maintenance problem record, ICOM traditions. The competition was in for a big surprise as it raced past everything in its field to become the most popular two meter crystal controlled radio on the market. Surprise. Surprise.

But the **IC-22A's** best surprise is the little surprise, its price. surprise. The little radio with all the big surprises is also the best FM transceiver value available. Engineered for versatility and sophistication: priced within the reach of the most modest beginner. Whether the **IC-22A** is your first FM or your last, you're in for a little surprise.



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MODULATION	Phase, F3
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1 Watt into 8 Ohms

VHF/UHF AMATEUR AND MARINE COMMUNICATION EQUIPMENT

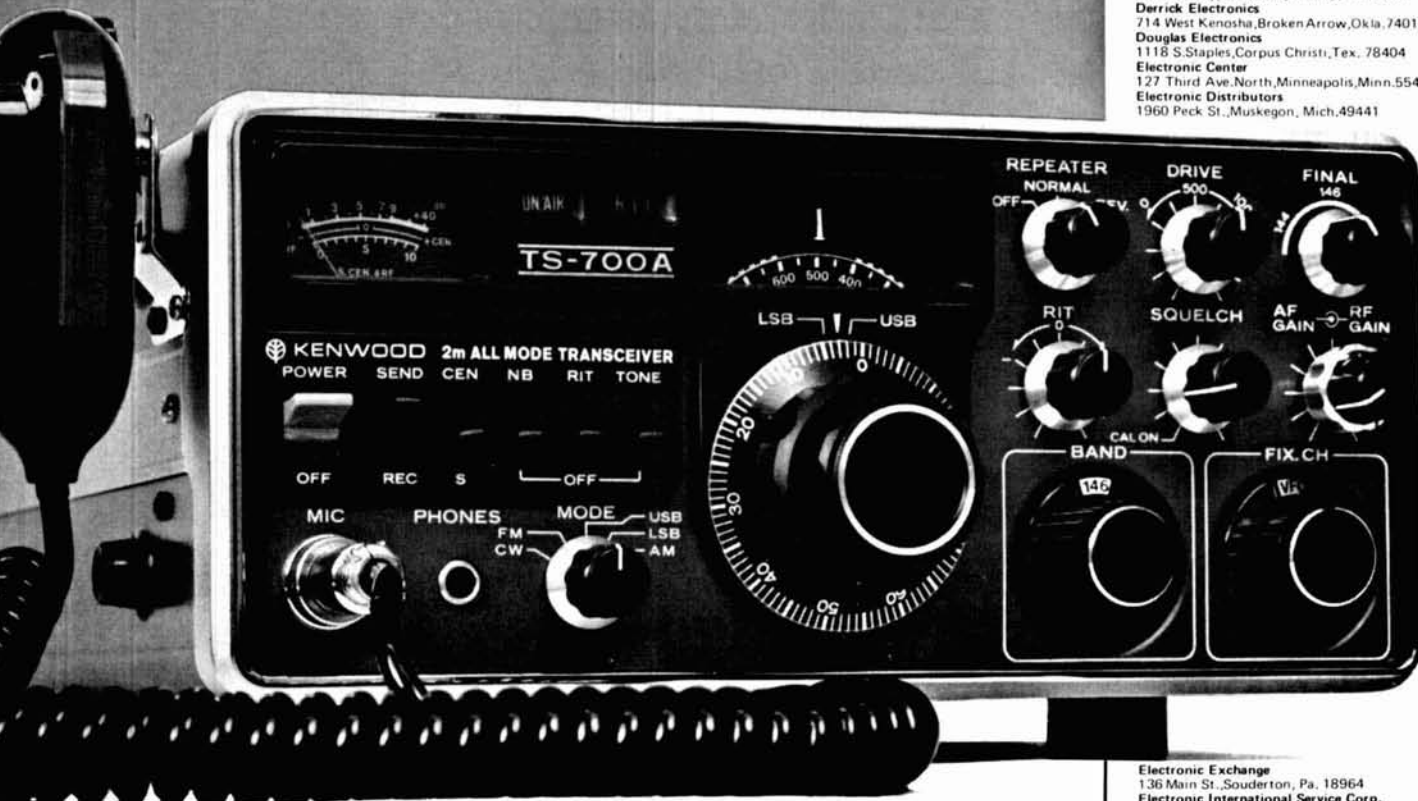
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A NEW WARC TASK FORCE for "Research and Support" was announced by Chairman John Johnston as the first item of business at the January 20th WARC '79 meeting in Washington. This Task Force will be headed by Dick Baldwin and will supply (through ARRL) the basic working group support for Amateur Radio WARC preparation he had promised at the December meeting.

The Proposed Frequency Table was then reviewed by the Task Force chairmen with no significant changes from those previously proposed (Presstop, February, 1976 issue). Asking and getting are different things, however. Other U.S. groups are reported to be after 3.9-4.0, 7.2-7.3, 146-148, and 220-225 MHz (see below), and broadcast would like to extend their a-m band upper limit from 1605 to 1805 kHz!

CB'S WARC MEETING on January 13th generated frequency recommendations of one MHz between 26-28; 5 MHz between 216-230 (220-225 MHz preferred), 10 MHz between 470-947 (around 900 MHz preferred), and 200 MHz between 15 and 25 GHz. Present Class-C (72 MHz) and Class-A (462/467 MHz) would remain unchanged.

SIGNING "MOBILE" OR "PORTABLE" with your call will never again be required if a just released Notice of Proposed Rule Making becomes part of the Amateur rules. Docket 20686 also proposes that the requirement for notifying the FCC before engaging in an extended period of portable operation be deleted.

Comment Due Date is February 27, with Reply Comments due on March 8. Though Docket 20686 would make it unnecessary to indicate portable or mobile operation, it would not prohibit such identification - a generally favorable Amateur response is expected, but such a rules relaxation could cause confusion in contests and for award programs.

FCC'S NEED FOR ENFORCEMENT "TEETH" highlighted FCC Chairman Richard Wiley's message to Congress in an appearance before the Senate Commerce Subcommittee January 20. He'd like to be able to double the size of the fines the Commission can levy, extend its authority to cover unlicensed as well as licensed radio operators since under the present rules unlicensed operators - principally CB violators - must be turned over to the Justice Department for prosecution after the FCC has tracked them down.

TRANSMITTER SPURIOUS OUTPUTS such as those previously reported from the Heathkit 2026 and early Multi-2000 are not the only problems facing buyers of vhf/uhf Amateur gear. Because of the potential interference to the many services using the higher frequencies, all receivers that tune above 30 MHz that are sold commercially must be FCC certified that they meet the limits on radiation specified in Part 15 of the rules.

Some Japanese Imports have come in without Part 15 certification and reports are that some uncertified equipment is being sold currently on the Amateur market.

CANADIAN AMATEURS requesting reciprocal privileges no longer have to have a U.S. mailing address - the change, which also applies to CB licenses, is effective immediately.

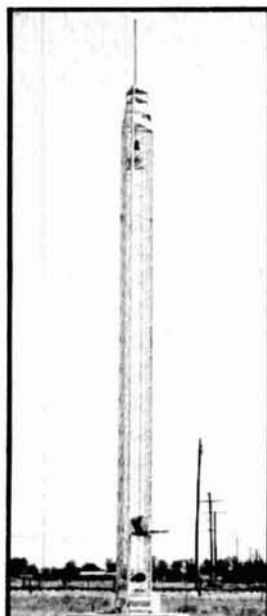
UNLICENSED AMATEUR-LIKE ACTIVITY by the "HF gang" operating on ssb in the region between channel 25 and 27.5 MHz grows at an ever increasing pace. Latest report is that 10,000 each of HF- and HFA- series "calls" have been assigned to these illegal stations and they are now well into the HFB- numbers! With rumors abundant that Class-D CB expansion to 27.5 MHz is due out shortly, it's not at all unlikely that we'll soon find more of them than licensed Amateurs on the 10-meter band.

Amateurs Can Assist FCC in their efforts to cope with this illegal tide by reporting to the FCC any information they pick up listening to the HFers that might help in identifying individual operators - some have been heard recently giving their complete street addresses for QSL purposes, and since their's is an entirely illegal operation, the restrictions concerning secrecy of communications do not apply. Reports can be sent to the Engineer In Charge of your nearest FCC Field Office, but better yet would be one of the four FCC Special Enforcement Facilities with a carbon to your local EIC. Write Supervisor, FCC SEF at P.O. Box 1588, Grand Island, Nebraska 68801; P.O. Box 65, Powder Springs, Georgia 30073; 2914 W. Edinger Avenue, Box 5126, Santa Ana, California 92701; or P.O. Box 36, Laurel, Maryland 20810.

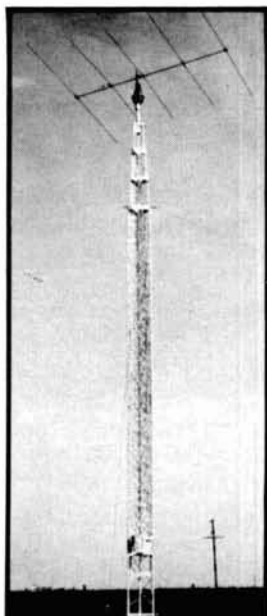
HIRAN DOCKET proposing shared use of 420-450 MHz band by the off-shore oil rig radio location system has finally made it into the home stretch and will be out very soon. Reports are that despite strenuous Amateur and Citizens Division opposition HIRAN will get to share the band on a temporary, non-interfering basis as Docket 20147 had initially proposed.

RCA WILL STOP TUBE PRODUCTION and close its historic Harrison, New Jersey plant July 30th. However, RCA will continue to make some types overseas and buy others from other makers so does plan to continue as a major tube supplier for some time to come.

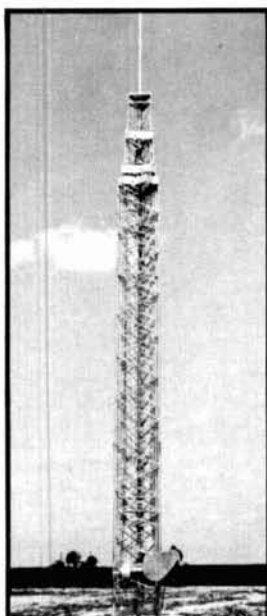
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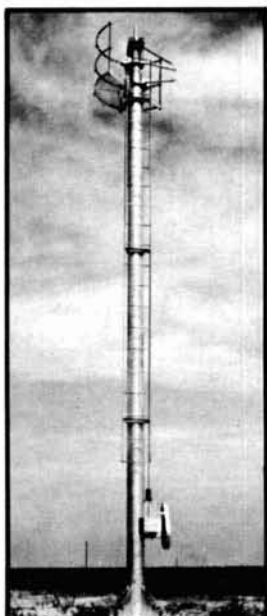
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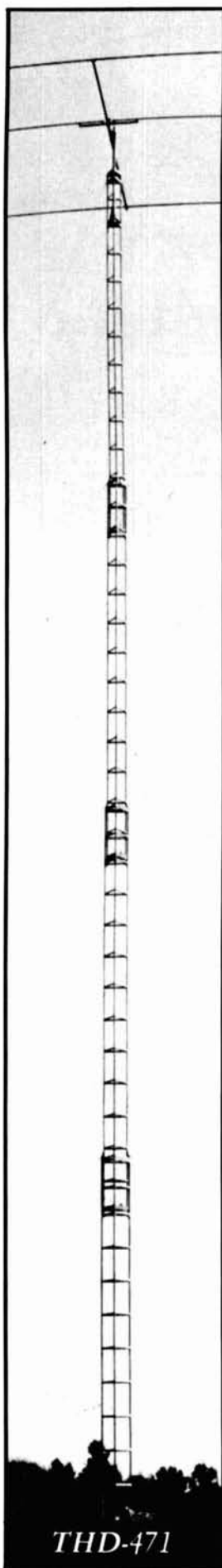
MW-65



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TM-370



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survey of crystal oscillators

A comprehensive review
of many circuits
with recommendations
to help you choose
the crystal oscillator
best suited
to your design needs

Crystal oscillators are fundamental to radio-communications equipment and, today, to many digital devices such as clocks, frequency meters, and some precision measuring instruments. Crystal-oscillator circuits abound, and design choice depends on the application and desired characteristics.

This article presents an overview of solid-state crystal oscillators, many of which have been gleaned from the literature. Unfortunately, many published circuits have unknown or little-understood characteristics, whereas others have inherent pitfalls that can trap the unwary. A major purpose of this article is to ferret out these questionable crystal-oscillator circuits and offer guidelines on what to expect if construction is contemplated.

Fundamental-frequency and overtone-frequency crystal oscillators are reviewed. Applications are presented for low- and high-frequency circuits, 1-MHz time-base clocks, TTL-compatible oscillators using ICs, variable-frequency oscillators (VXOs), oscillator-multipliers, and multichannel (switchable) oscillators. The article is prefaced with a short discussion on quartz-crystal resonant modes, which is necessary to an understanding of how these crystals operate in an oscillatory circuit.

It's sometimes desirable to know something of the various crystal cuts for a particular application; such a discussion is beyond the scope of this article. References 1 to 8 contain suitable material; references 1 to 5 are particularly recommended.

One thing little appreciated about quartz crystals is that the crystal can oscillate in two resonant modes: parallel and series. The two resonant frequencies are separated slightly, typically 2 to 15 kHz. The series-resonant frequency is lower than the parallel-resonant frequency. Oscillator circuits are designed so that the crystal oscillates in one of these modes. Few articles note that a crystal specified and calibrated for use in a parallel-mode circuit may be satisfactorily used in a series-mode circuit if a capacitor equal in value to the circuit's specified parallel-mode load capacitance (usually 20, 30, 50 or 100 pF) is placed in series with the crystal. Unfortunately, the converse isn't true. The series-mode crystal will oscillate above its calibrated frequency in this case, and it's usually impossible to pull it down sufficiently with capacitive loading.

Overtone crystals always operate in the series mode, usually on the 3rd, 5th or 7th overtone, and manufacturers usually calibrate the crystal at the overtone frequency, *not* at the fundamental frequency. Operating a crystal in the parallel mode and multiplying the frequency three or five times doesn't produce the same result as operating the same crystal in the series mode on its third or fifth overtone. When ordering overtone crystals, avoid confusion and specify the frequency you want, not the apparent fundamental frequency!

For crystals used in parallel-resonant-mode oscillator circuits, the load capacitance must be specified, as stated above. Take into account device input capacitances, circuit capacitance across the crystal, and strays. A load capacitance of 30 pF is the most usual specified value. A trimmer is often used in parallel-mode circuits for exact frequency setting and is a desirable feature. When ordering crystals to be used in the series mode, a load capacitance is not specified.

Crystal oscillator circuits can be divided into two modes of operation: fundamental-frequency oscillators and overtone oscillators. Fundamental-frequency crystals cover the frequency range to 20 MHz, although fundamental-frequency crystals above 15 MHz are uncommon and very fragile. Fundamental-frequency crystals are usually specified for parallel-mode operation, but series mode can be requested. Low-frequency crystals, below 500 kHz, are often best operated in the series mode. Overtone crystals cover 15 to 150 MHz.

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Overtone crystals above 100 MHz are usually fragile and expensive but are handy for uhf oscillator-multiplier chains.

The choice of a circuit will depend on your application. Various applications will require sine-wave output, square-wave output or a harmonic-rich output, for example. Other applications may require an oscillator to accept crystals covering a wide frequency range or an oscillator to drive a TTL digital device.

In any crystal oscillator circuit it's desirable to have some means of setting or trimming the frequency and to be able to adjust the feedback, easily and in a noncritical manner, to limit crystal power dissipation. Being able to control the feedback has other advantages, as we shall see later. The most convenient way to adjust feedback is to vary resistors or capacitors. Coil taps and tickler windings don't provide the same ease of fineness of adjustment.

The permissible maximum power dissipation of crystals in the 1 to 20 MHz range, operating in the fundamental mode, is about 200 microwatts and is similar for overtone operation. Most low-frequency crystals, below 1 MHz, have a permissible maximum power dissipation of 100 microwatts and should be operated with a dissipation below 50 microwatts. Operating a crystal above or near this level degrades its stability, and the circuits chosen here avoid this problem by limiting the dissipation.

The equivalent crystal series resistance, which determines its activity, determines crystal power dissipation. The higher the series resistance, the lower the permissible power dissipation. Reference 5 gives a representative list for those interested. Using an 807 tube with 600 volts on the anode in a Pierce crystal oscillator is not recommended — you'll probably fracture the crystal. The main point to remember is that crystal oscillators are meant to provide a stable frequency source, *not* power output. Frequency stability, both short and long term, and crystal life are compromised when an oscillator is operated at an excessive power level. In all applications it's wise to use a regulated source of supply voltage.

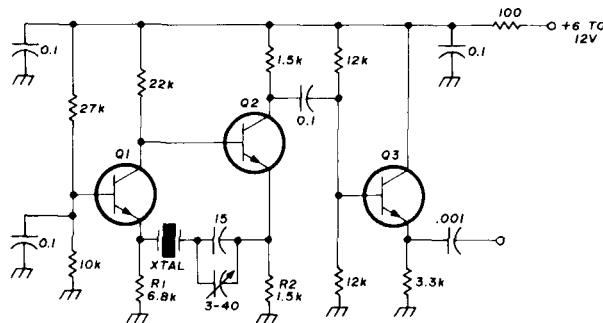
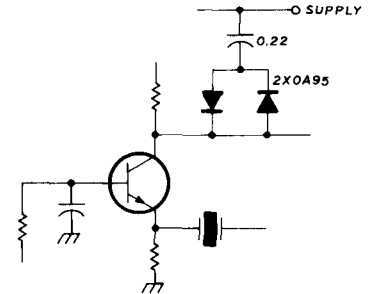


fig. 1. Aperiodic (Butler) oscillator; a series-mode oscillator with sine-wave output. Reducing R2 to about 1k will produce good harmonics to 30 MHz with a 100-kHz crystal. Transistors Q1, Q2 and Q3 are 2N918, 2N2222, 2N3563, 2N3564, 2N3693, 2N3694, 2N5770, AY1119, BC107, BC108, BC109, BC547, BC548, BC549, or SE1001.

aperiodic oscillators

These circuits don't use tuned circuits and can operate over a very wide frequency range. The only component that requires changing for a change in frequency is the crystal. This can be a very useful advantage, whether the circuit is used simply as a "crystal checker" or in some other application. For low-frequency crystals, tuned circuits tend to be bulky, and an aperiodic oscillator has a distinct advantage. However, such oscillators aren't without drawbacks. Some low-frequency crystals,

fig. 2. Adding diodes to the circuit of fig. 1 limits oscillator amplitude and hence crystal power dissipation; starting performance is also improved.



particularly DT and CT cut, are prone to oscillation on unwanted modes.

When using an aperiodic oscillator, it's wise to check that the output is on the correct frequency and that no mode instability exists. With these crystals, the *esr* (equivalent series resistance) of higher-order oscillation modes is often less than the fundamental-mode *esr*. As a consequence, the crystal oscillates more readily in the undesired mode. One way around this problem in an aperiodic oscillator is to use a transistor with high small-signal gain at low frequencies that decreases rapidly above the desired operating frequency. In extreme cases, an oscillator with a tuned circuit may be necessary.

The circuit in fig. 1 is an aperiodic Butler oscillator. The basic circuit was first published in *VHF Communications*⁹ and has since appeared in various versions in other amateur publications. A similar circuit is discussed by M. Lane⁶ (see also fig. 3). The output of the circuit in fig. 1 is essentially a sine wave, although the second and third harmonics are not much attenuated. Reducing the Q2 emitter resistor increases the harmonic output. Reducing this resistor to about 1k will produce good harmonics to 30 MHz from a 100 kHz crystal. Being a Butler oscillator, it's a series-mode circuit. Oscillation is noncritical with supply voltage variation, although frequency stability is affected. A regulated supply is recommended for applications where stability is important.

As indicated, a variety of transistors may be used. For crystals above 3 MHz, transistors with a high gain-bandwidth product (f_T at least 100 MHz) are recommended. For crystals in the 50 to 500 kHz range, transistors with high low-frequency gain, such as the 2N3565 or BC549, are recommended. Low-frequency crystals, as mentioned before, have a permissible power dissipation limit of 100 microwatts, and amplitude limiting may be necessary. Low supply voltage, consistent with reliable starting, is one way of achieving this. The addition of diodes to the circuit, as in fig. 2, is probably a better

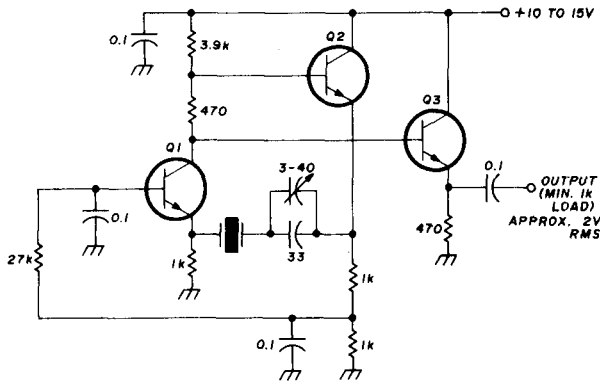


fig. 3. Aperiodic emitter-coupled oscillator (after Lane, reference 6). This circuit is somewhat frequency sensitive to power-supply voltage variations and load changes despite buffered output. Transistors Q1, Q2, and Q3 are 2N3646, 2N3013 or MPS3646.

method, and starting performance is improved. The circuit will oscillate with fundamental-mode crystals to at least 15 MHz with appropriate values of R1 and R2 as well as the appropriate transistors. As shown in the circuit, an emitter follower (or source follower) is recommended.

The aperiodic oscillator in fig. 3 is discussed by Lane,⁶ and comments similar to those above apply here. It is also slightly frequency sensitive to power-supply voltage variations. Load changes also affect frequency stability slightly despite the buffered output. A minimum load of 1k is desirable.

The two oscillator circuits just described are series-mode oscillators adapted to accept parallel-mode crystals. When using a known series-mode crystal, the trimming capacitance in series with the crystal should be replaced by a short circuit.

An aperiodic parallel-mode oscillator is shown in fig. 4. It's a wideband dc amplifier, with the crystal providing feedback. A crystal operating in the parallel mode has a 180-degree phase reversal across it; consequently, here it provides positive feedback. The 3 to 30 pF trimmer from Q1 base to ground is for frequency setting. A buffer is recommended. The output is not a pure sine wave and the harmonic level is fairly high.

There are many other aperiodic oscillator circuits, but the three discussed here have proven to have repeatable characteristics. Most IC TTL oscillators are aperiodic, but their application is in digital equipment generally, and they are covered in a later section.

low-frequency oscillators

Crystals in the 50 to 500 kHz range are commonly CT or DT cut, but regardless of the cut, they require special considerations not encountered with the more common AT- or BT-cut crystals used in the high-frequency range. As mentioned previously, their *esr* is usually high and they are prone to oscillating in a higher-order mode, usually at twice the fundamental frequency.

The circuit in fig. 5 has two advantages. It doesn't require a tuned circuit and you have a choice of either

sine- or square-wave output. For crystals in the 20 to 150 kHz range, 2N3565, 2N2920 or 2N2979 transistors are recommended to avoid mode-instability problems. Any of the other types listed are satisfactory for crystals in the 150 to 500 kHz range. Frequency stability and mode stability are good, and the circuit makes an excellent oscillator for troublesome FT241 crystals. If the crystal won't start reliably, it probably has a high *esr*. In this case increase R1 to 270 ohms and R2 to 3.3k. For square-wave operation, C1 is 1 μ F or a standard value either side. Do not use an electrolytic capacitor. C1 is deleted for sine-wave operation. Harmonic output for sine-wave operation is quite low; the second harmonic is typically -30 dB or more.

A somewhat simpler, parallel-mode, low-frequency oscillator is shown in fig. 6. It makes an excellent bfo for 455 kHz. Resistor R_f controls the feedback. If the oscillator won't start, reduce the value of R_f. Increasing the value of R_f reduces harmonic output, a very handy feature. However, at the reduced level of feedback, the oscillator can take up to 20 seconds to reach full output. Harmonic output can be reduced to better than -40 dB.

To produce an output rich in harmonics, bypass the transistor 100-ohm emitter resistor with a 0.1 μ F capacitor. Output will rise to about 3 volts rms. Power supply voltage is best kept below 9 volts in this case. For crystals having a specified load capacitance of 30 or 50 pF, remove the 100 pF capacitor in series with the crystal.

Another simple circuit is shown in fig. 7. It has a minor disadvantage in that it requires a coil — usually a bulky component. No coil data is given, but proprietary prewound coils of the indicated inductance range are an excellent solution. This circuit allows a simpler arrangement than that of fig. 6, if switched crystals are desirable. The switch contacts should be inserted between C1 and L1 with each crystal having its own coil. Intercontact capacitance across the switch contacts should be low. Adjusting the slug in L1 pulls the crystal frequency.

The circuit of fig. 7 is basically a series-mode circuit. Parallel-mode crystals can be used by making C1 equal to the specified load capacitance as mentioned earlier. Performance is similar to the circuit of fig. 6; harmonic output is usually better than -30 dB. CT- and DT-cut crystals are usually used to cover 100 to 500 kHz. These

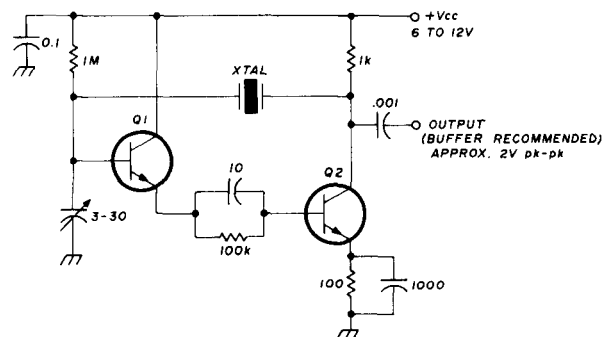


fig. 4. Aperiodic parallel-mode oscillator. The trimmer capacitor sets the frequency. A buffer is recommended to overcome loading problems. Q1 and Q2 are 2N914, 2N918, 2N3565, 2N5770, BC109 or BC549.

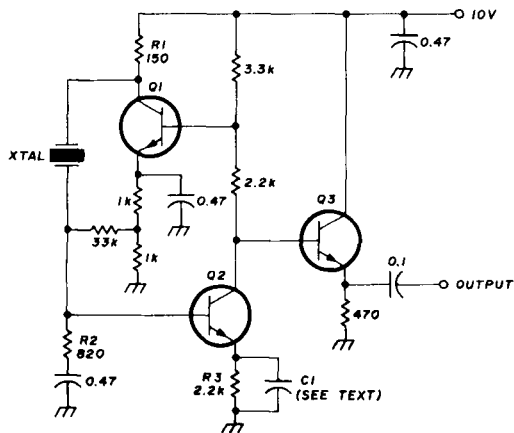


fig. 5. A low-frequency series-mode oscillator (after Lane, reference 6). No tuned circuit is required and either sine- or square-wave output is possible. Circuit is excellent for troublesome FT241 crystals. Output is approximately 1.0 to 1.5 volt rms sine wave or 4-volt square wave (see text).

	for 20-150 kHz crystals	for 150-500 kHz crystals
Q1, Q2, Q3	2N3565	BC107, BC547
	2N2920	2N3565
	2N2979	2N5770
		2N2222

crystals are prone to oscillating at twice their fundamental frequency; for this reason, the circuit in fig. 7 is recommended where such trouble may be experienced.

For crystals in the 40 to 100 kHz range, the +5-degree X cut is common. The GT cut was once common for this range (up to 250 kHz), and surplus crystals may be of this type. The circuit in fig. 8 is recommended for these crystals or where really cantankerous low-frequency DT-cut crystals are encountered. To trim the frequency of series-mode crystals, tune the slug in L1. For parallel-mode crystals, C2 may be replaced by a capacitor about two-thirds the specified load capacitance in parallel with a 3 to 30 pF trimmer. The trimmer then serves as the frequency adjustment and L1 is peaked for maximum output. The use of a buffer is recommended.

A circuit seen commonly in the literature is that of fig. 9. It works quite well, most of the time, but suffers from a number of disadvantages. Feedback is dependent on the gate-drain capacitance, a highly variable quantity; stability suffers. It is prone to a) frequency pulling with load changes despite good buffering, and b) output-level

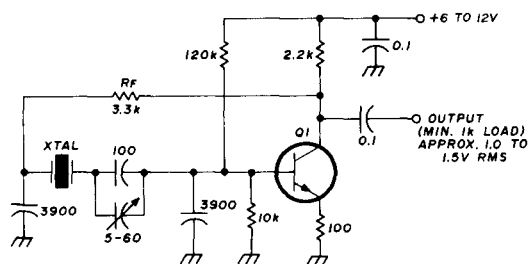
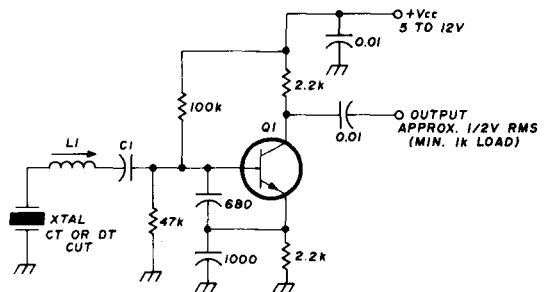


fig. 6. Low-frequency (50 to 500 kHz) parallel-mode oscillator (after Lane, reference 6). Feedback-control resistor R_f may be decreased for hard-to-start crystals; increasing R_f reduces harmonic output. Q1 is a 2N2920, 2N2979, 2N3565, 2N3646, 2N5770, BC107 or BC547.

variations. Performance is not always repeatable. Starting performance varies greatly between fets of the same type and with various crystals.

1 MHz oscillators have many applications, such as frequency markers, clock oscillators and time-base references. The circuit in fig. 10 is recommended where a high-stability 1 MHz source is required. It has a basic stability of 1 part in 10^{-6} or better with supply variations and the usual atmospheric-temperature variations. Using an inexpensive, commercially available crystal oven, it can maintain a stability approaching 1 part in 10^{-8} per day. Harmonic output is low. The output level is about 2 volts peak-to-peak. A TTL-level output is readily obtained by driving a 7413 Schmitt trigger. The circuit originally appeared in *Electronics*.¹⁰

A simple, general-purpose, parallel-mode, 1-MHz crystal oscillator, fig. 11, uses circuit constants for fundamental crystals in the 800 kHz to 3 MHz range. Output is a sine wave at about 0.5 volt rms into a 1k load.

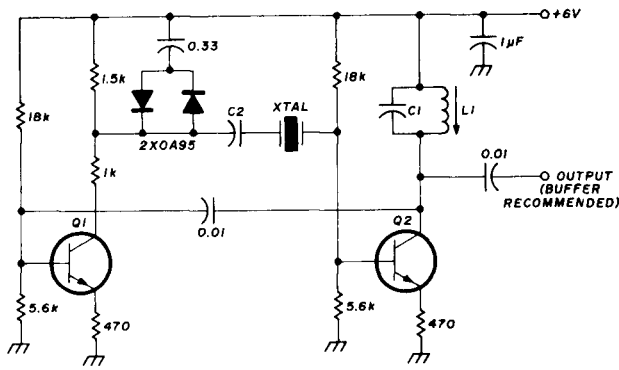


mode	C7	freq (kHz)	L (μH)
series	.01 μF		
parallel	use specified load capacitance (30, 50 or 100 pF)	150-300	800-2000
		300-500	360-1000

fig. 7. Low-frequency (150 to 500 kHz) oscillator (after Foster and Rankin, reference 7). Adjusting slug in L1 pulls crystal frequency. Circuit is basically series mode, but parallel-mode crystals can be used by making C1 equal to the specified load capacitance. Q1 is a 2N3563, 2N3564, 2N3693, BC107, BC547, or SE1010.

Harmonics are better than -35 dB down, although this is dependent on the transistor and the power-supply voltage used. Note that C1 differs for different crystal-load capacitances.

Integrated circuits are coming into increased use in communications equipment. Their versatility and performance present obvious advantages over discrete circuits. The circuit of fig. 12, which uses the LM375, an IC designed especially for oscillator applications, comes straight from the National Semiconductor *Linear IC Data Book*. I've found its performance to be very good. The application shown here is for a TTL-compatible output. A sine wave output is obtained by deleting the TTL buffer and feeding the oscillator output into the linear input (pin 3) of the buffer, bypassing the limiting input (pin 2) with a 0.01 μF capacitor. Harmonic output is quite low.



L7	C7	mode	C2	
50 kHz	2 mH	0.01 μF	series	1000 pF
100 kHz	1 mH	2200 pF	parallel	2/3 specified load capacitance (i.e., 30, 50, 100 pF)

fig. 8. Low-frequency oscillator with tuned circuit (after Foster and Rankin, reference 7). Recommended for GT-cut (surplus) crystals in the 40 to 100 kHz range or for hard-to-start DT-cut crystals. Series- or parallel-mode crystals may be used. Q1 and Q2 are 2N2979, 2N3565, 2N5770, BC107, BC109, etc.

This is a parallel-mode oscillator. Load isolation with the buffer is extremely good; wide variations in load have negligible effect on frequency. Note the low output impedance of the buffer. The circuit constants given work with crystals between 800 kHz and 3 MHz. Output voltage depends on the power-supply voltage. When using the buffer in the linear mode, a supply of up to 24 volts can be used.

high-frequency oscillators

Modern crystals manufactured for fundamental operation between 3 and 20 MHz are generally AT cut, whereas the older FT243 crystals were generally BT cut. The AT-cut crystal has about an order-of-magnitude better temperature stability performance than the BT cut, but the latter produces thicker crystal blanks, which are far more robust, particularly at the upper end of the range. However, an oven-controlled BT-cut crystal has stability somewhat better than an AT cut crystal, even in an inexpensive commercial oven (see "Oscillator Topics" in reference 11).

The first circuit (fig. 13A) is described by Lane⁶ and has the advantage of not requiring a tuned circuit. It is,

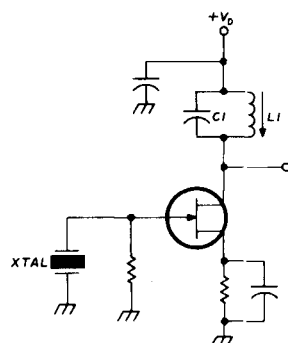


fig. 9. Fet crystal oscillator often seen in the literature. Circuit suffers from frequency pulling with load changes. Performance repeatability is questionable.

of course, the same circuit as in fig. 6 but adapted to the high-frequency range. This circuit is recommended for noncritical applications where high harmonic output is desired. It particularly suits FT243 crystals, which may have a high *esr*. Stability is improved and harmonic level reduced when resistor R_f is increased. However, as noted previously, the circuit takes longer to reach full output.

The addition of a tuned circuit, as shown in fig. 13B, considerably reduces harmonic output. The tuned circuit should have a high unloaded Q for best results. With an unloaded Q of 50 and R_f of 3.9k, the second harmonic was 35 dB down. When a coil having an unloaded Q of 160 was substituted (R_f still 3.9k), the second harmonic decreased to -50 dB. Output voltage also increases with a high-Q coil. A link winding on the coil, or a capacitor from the transistor collector, can be used for output coupling. Tuning the coil pulls the frequency, but this adjustment is generally made only once and pulling is thus of little consequence. An output buffer is recom-

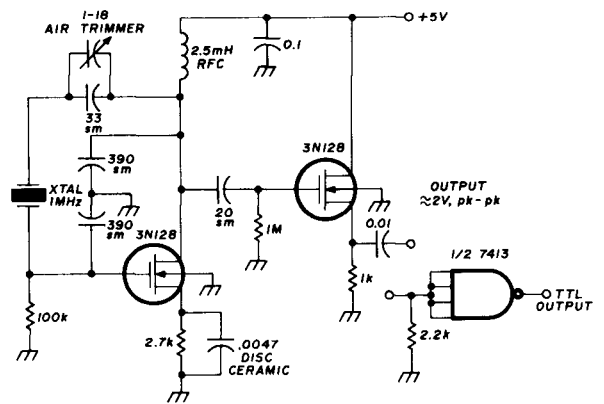


fig. 10. Recommended circuit for a highly stable 1-MHz source. With an inexpensive oven, stability approaching 1 part in 10^{-8} per day is achievable.

mended to reduce frequency pulling with load variation. The circuit is for parallel mode operation. A temperature stability of ± 10 ppm, largely dependent on the crystal, is readily achieved over the temperature range 32° to 140° F (0° to 60° C).

Another simple circuit that doesn't require a tuned circuit appears in fig. 14A. This circuit is described by Foster and Rankin,⁷ and variations are common in the literature. Some use an rf choke or tuned circuit in place of R_1 , although this isn't necessary. More output can be obtained by putting a 1.5k load resistor in the collector of Q1 and taking output from the collector, as shown in fig. 14B. About twice the output level may be obtained than in fig. 14A. A TTL output can be obtained using the combination of fig. 14B and C. However, sufficient drive for a counter or other TTL device may be difficult to obtain at the upper end of the frequency range.

In contrast to the untuned version of fig. 13A, the harmonic output of fig. 14A is quite low. It depends on the transistor and the power-supply voltage, but the harmonic level is generally better than -30 dB. Frequency

stability is affected about 0.001% with supply variation between 5 and 10 volts. A temperature stability of +10 ppm can be expected, as for fig. 13A, over the range 32° to 140°F (0° to 60°C).

The circuit in fig. 15 is suitable for crystals specified for operation in the series mode. Coil L1 is adjusted to set the frequency. Performance is similar to the circuit of fig. 14A. This circuit is otherwise known as the "impedance-inverting" circuit. To set it up and to ensure that the coil resonates near the crystal frequency, apply a short circuit across the crystal terminals and tune the coil until the output is close to frequency, then remove the short and tune L1 to set the correct frequency.

Under no circumstances should a tuned circuit be placed in the Q1 collector that resonates to the crystal frequency. The circuit may then oscillate as a tuned-base, tuned-collector oscillator not under control of the crystal. A tuned circuit on a multiple of the crystal frequency can be used for frequency multiplication, where

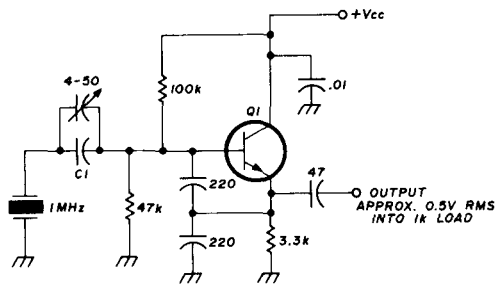


fig. 11. Parallel-mode 1-MHz oscillator usable with crystals between 800 kHz to 3 MHz. Output is a sine wave at about 0.5 volt rms into a 1k load. Note that C1 differs for different crystal-load capacitances. Q1 is a 2N3563, 2N3564, 2N3693, 2N5770, BC107, BC547 or SE1010.

a minimum number of components and frequency multiplication are required. Take the output from the collector circuit in such case. (These comments also apply to fig. 14A.)

The oscillator in fig. 16A is discussed in detail by Lane.⁶ It's a series-mode oscillator, but parallel-mode crystals can be used, as discussed earlier. Adjust feedback by varying the ratio of C1 and C2. Tune the slug in L1 for frequency trimming.

Resonating L1 is quite simple. Using a grid-dip oscillator resonate L1 with C1 in parallel. In-circuit adjustment can be made with the grid-dip oscillator. Short circuit the crystal and dip the inductor to frequency. Check circuit oscillation by shorting the crystal and applying supply voltage. Tune L1 until output is close to the crystal frequency, then remove the short and tune the slug in L1 to pull the crystal exactly onto frequency. A buffer is recommended as the frequency is sensitive to load variations. Less variation occurs with supply voltage variation.

Crystal power dissipation can be varied by adjusting R1, whose value should be between 100 and 1000 ohms.

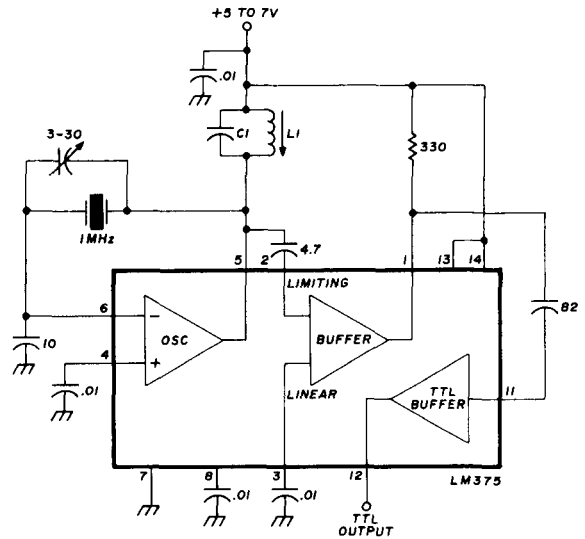


fig. 12. A 1-MHz IC oscillator with TTL-compatible output. Performance is good; harmonic output low. Circuit constants are for crystals between 800 kHz to 3 MHz. C1-L1 resonates at the crystal frequency; if L1 = 0.5 mH rfc, C1 = 47 pF in parallel with 30 pF trimmer.

The lower the value, the lower the crystal power dissipation and the better the stability. Output will drop a little with lower values of R1. A temperature stability of 10 ppm can be obtained with this circuit.

Fet fundamental-frequency crystal oscillators derive directly from vacuum-tube technology. Figs. 17, 18 and 19 illustrate the use of fets. When using mosfets, gate bias is obtained by the diode from gate to ground, as in figs. 18 and 19. Figs. 17 and 18 are the familiar Colpitts oscillator. Harmonic output is low and depends on the fet used. Crystal power dissipation is reduced by reducing C1 capacitance.

Fig. 19 is a Miller oscillator that seems to provide improved performance over most circuits of this type. The circuit also illustrates the single-stage oscillator-

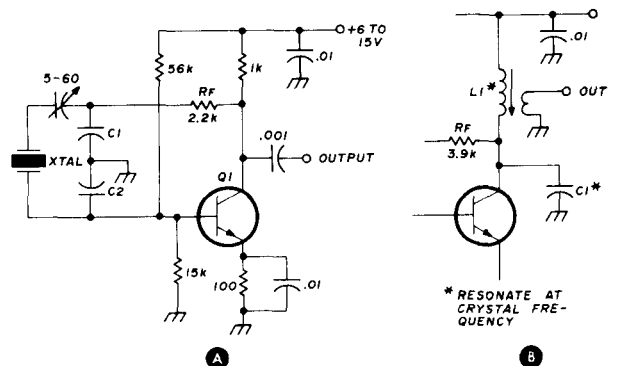
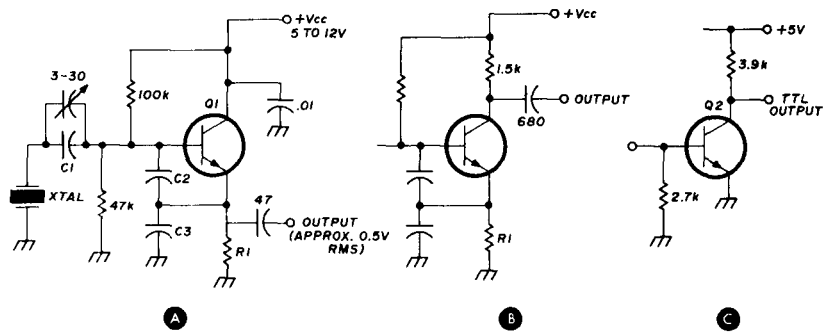


fig. 13. Fundamental-frequency, parallel-mode oscillator for 1 to 18 MHz (A). A buffer is recommended. Adding a tuned circuit (B) reduces harmonic output. Q1 is a 2N916, 2N918, 2N3564, 2N5770, BC107, BC108, BC109, BC182, BF180, BF200, SE1001 or SE1002.

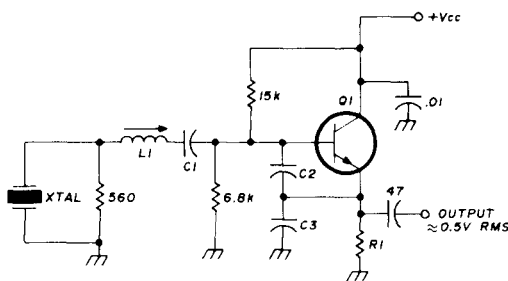
crystal freq (MHz)	C1 (pF)	C2 (pF)
1-3	470	820
3-10	220	470
10-18	120	330

fig. 14. Another version of a fundamental-frequency, parallel-mode high-frequency oscillator requiring no tuned circuit (A). Circuit (B) delivers about twice the output than (A). TTL output can be obtained using the combination of (B) and (C). Q1 is a 2N3563, 2N3564, 2N3693, 2N5770, BC107, BC547, BF180 or BF200; Q2 is a 2N3478, 2N3932, 2N3933, 2N4259 or 2N5179. Other component values are shown at bottom right.



crystal freq (MHz)	C2 (pF)	C3 (pF)	R1 (ohms)	C1
3-10	150	150	2.7k	120 pF for 50 pF specified load capacitance; 39 pF for 30 pF specified load capacitance
10-20	82	82	1k	none for 20 pF specified load capacitance

multiplier application. A tuned circuit resonating at a multiple of the crystal frequency can also be placed in the oscillator drain circuits of figs. 18 and 19. A temperature stability of 15 to 20 ppm can be expected from these circuits over the operating temperature range of the crystal (assuming use of the AT or BT cut). Parasitics can be troublesome with these circuits, as most fets have good gain well into the vhf range. A 10- to 47-ohm resistor in series with the gate lead, as shown in fig. 17, usually overcomes the problem.



crystal frequency	C1	C2, C3	R1	L*
3-10 MHz	1000 pF	270 pF	1500 ohms	2-4 MHz, 60 turns; 4-6 MHz, 40 turns; 6-10 MHz, 25 turns
10-15 MHz	100 pF	220 pF	680 ohms	15 turns
15-20 MHz	100 pF	100 pF	680 ohms	10 turns

*All inductors closewound with no. 33 (0.2mm) enamelled wire on 1/8" (6.5mm) diameter slug-tuned coil form.

fig. 15. High-frequency oscillator circuit suitable for crystals specified for series-mode operation. Known as the "impedance inverting" circuit, its performance is similar to the circuit of fig. 14A. Q1 is a 2N3563, 2N3564, 2N3963, 2N5770, BC107, BC547, BF180, BF200 or SE1010.

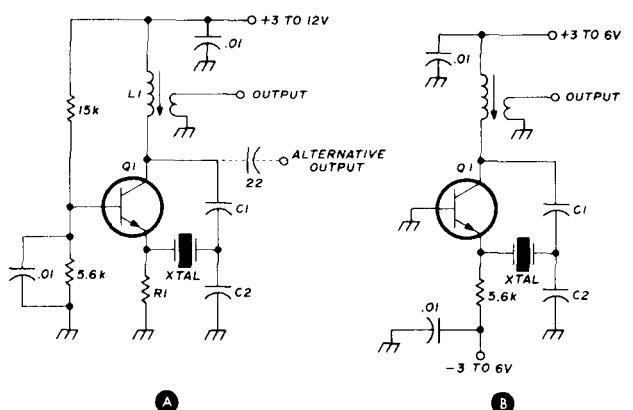
Fig. 20 is a high-frequency version of the circuit in fig. 12, using the LM375 IC. Output voltage depends on the supply voltage. The circuit will oscillate with a supply voltage down to 4 volts. Tuning L1 will pull the crystal frequency, but this adjustment should not be used to trim the frequency. Tune L1 only for maximum output. If C3 is a 3 to 30 pF trimmer, it should be used to set the crystal to frequency. Again, harmonic output is low. Using a tuned circuit in the buffer output is likely to cause the circuit to oscillate of its own accord, uncontrolled by the crystal. Use a high-Q tuned circuit for L1/C1 if possible. Stability approaches the crystal speci-

fications; however, the circuit is sensitive to supply-voltage variations.

The buffer provides excellent load isolation and has a low output impedance. Fig. 21 is the series-mode version of the circuit in fig. 20. In this case L1 can be used to trim the crystal frequency. Similar comments apply for the other characteristics.

TTL IC oscillators

I've made brief mention of obtaining TTL-compatible outputs from crystal oscillators to drive digital circuitry (under 1 MHz oscillators). If the output level of an oscillator is sufficient, around 2 volts peak, a 7413 Schmitt trigger makes a good TTL-output buffer, as in fig. 10.



crystal freq (MHz)	C1 (pF)	C2 (pF)
3-10	47	390
10-20	22	220

the lower will be crystal power dissipation and the better the stability. Q1 is a 2N918, 2N3564, 2N5770, BC107, BC108, BF115, BF180, BF200, SE1001 or equivalent. L1 resonates to crystal frequency with C1.

Another solution is illustrated in fig. 14, where oscillator output may be below 1 volt (but it must be at least 0.6 volt peak).

The combination of a discrete oscillator followed by a TTL buffer may, however, present problems where space is limited, although the circuits in fig. 14 can be made fairly compact. The LM375 IC provides one solu-

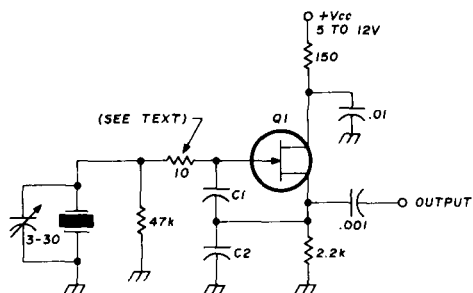


fig. 17. Fundamental-frequency, parallel-mode oscillator using a Jfet. Familiar Colpitts circuit is used. Q1 is a 2N3819, 2N5245, 2N5459, 2N5485, MPF102, or MPF104-106.

crystal freq (MHz)	C1 (pF)	C2 (pF)
3-10	27	68
10-20	10	27

tion, although a tuned circuit must be used. For low cost and convenience or where space is at a premium, the common TTL gates can be pressed into service and, indeed, are in common use. Fig. 22 illustrates a common method of using a 7400 NAND gate as a crystal oscillator. Two gates are biased into their linear region and coupled as an oscillator with the crystal in the feedback path. A third gate is used as a buffer.

These three circuits (figs. 22, 23 and 24) are aperiodic and would certainly have applications where a high output, aperiodic oscillator is called for. They make excellent frequency markers. Temperature stability is somewhat worse than that of discrete circuits. If you need a very stable oscillator in your counter, you'll just have to make room for more circuitry.

The circuit of fig. 22 will accept crystals from 1 to 10 MHz. Some trouble may be experienced with crystals

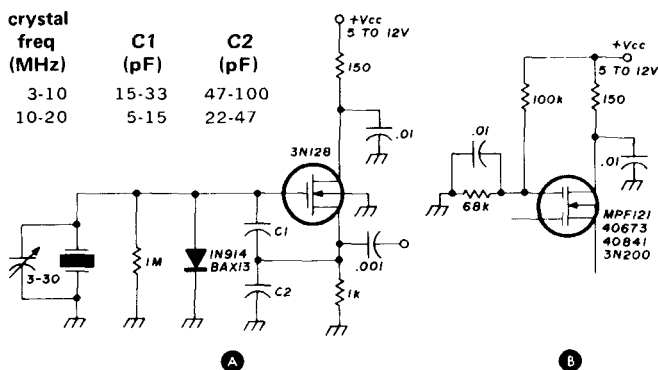


fig. 18. IGFET fundamental-frequency, parallel-mode oscillator using single-gate (A) and dual-gate (B) transistors. As in the circuit of fig. 17, harmonic output is low and depends on the device used.

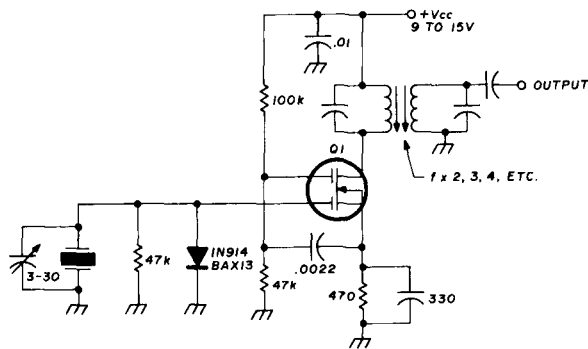


fig. 19. Fundamental-frequency, parallel-mode Miller oscillator illustrating single-stage oscillator-multiplier application. A tuned circuit resonating at a multiple of the crystal frequency can be placed in the drain circuit in this arrangement and that of fig. 18. Q1 is a 3N200, 2N209, 3N210, 40673, 40841, or MPF 121.

above this frequency. Occasionally, trouble may be had with unreliable starting performance, which is largely a function of the two bias resistors. Change their value up or down by using the nearest preferred value to see what effect it has. A wide variation should not be necessary. Frequency and starting performance are critically dependent on supply voltage.

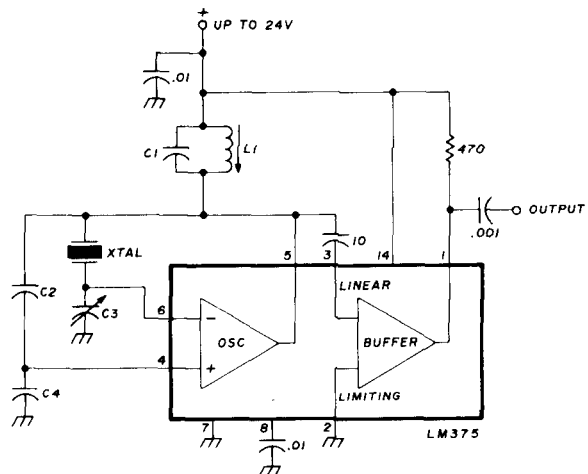


fig. 20. A high-frequency version of the circuit of fig. 12, using the LM375 integrated circuit. L1-C1 is resonant at the crystal frequency. Coil L1 should be tuned for maximum output only, not to trim the crystal frequency. A tuned circuit is not recommended in the buffer output to avoid self-oscillation.

Where it may be inconvenient to use a NAND gate, a NOR-gate oscillator can be substituted, using a 7402 or other TTL type, as shown in fig. 23. This circuit has performance similar to the circuit of fig. 22. Here, also, trouble may be experienced with starting: vary the gate bias resistors, as mentioned above.

The circuit in fig. 24 overcomes problems with poor

starting performance and has a higher upper-frequency limit than those of figs. 22 and 23, approaching the limit of the NAND gate used. I've used this circuit successfully with crystals over the range 1 to 20 MHz and have experienced no trouble. It starts reliably every time, even with crystals having a high *esr*. I thoroughly recom-

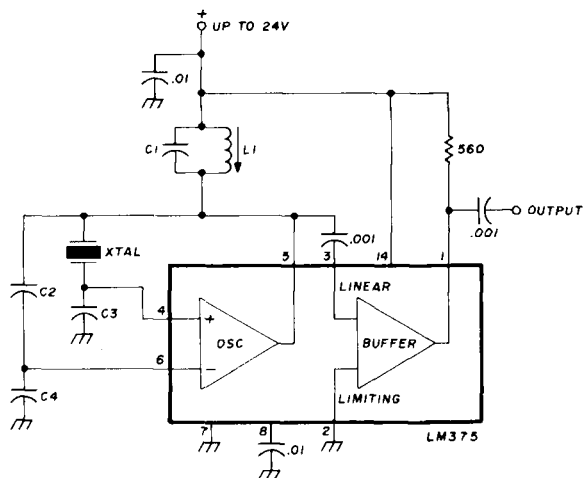


fig. 21. Series-mode version of the circuit in fig. 20. L1-C1 is resonant at the crystal frequency; L1 can be used to trim the crystal frequency in this case.

crystal freq (MHz)	C2 (pF)	C3 (pF)	C4 (pF)
3-10	68	68	330
10-20	27	27	120

mend it. The circuit comes from K1PLP¹² and is after Weggeman.¹³ For a good discussion on TTL oscillators I recommend both references.

When constructing oscillators using TTL ICs it's wise

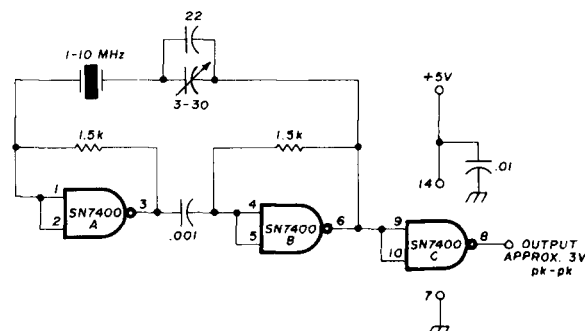


fig. 22. TTL NAND-gate crystal oscillator useful for applications requiring a high-output aperiodic oscillator. Crystals between 1 to 10 MHz can be used.

to bypass the power supply pin as close to the IC pin as possible. Keep the ground lead short, too.

overtone oscillators

Modern crystals manufactured for overtone operation are usually AT cut, although the BT cut is sometimes found. Take heed of the comments on overtone crystals in the introductory paragraphs of this article. All over-

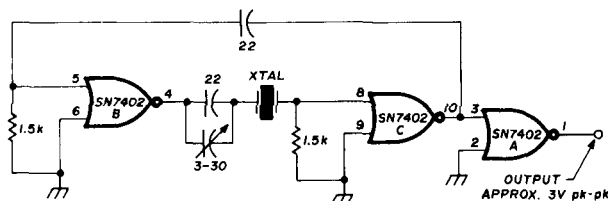


fig. 23. NOR-gate version of the circuit in fig. 22. Difficult crystal starting may occur in these TTL gate circuits, in which case the gate bias should be varied.

tone circuits operate with the crystal in the series mode. Overtone crystals are calibrated at the overtone frequency, not the apparent fundamental.

An overtone oscillator should not require excessive drive for the crystal to oscillate on the overtone frequency and should have some provision separate from

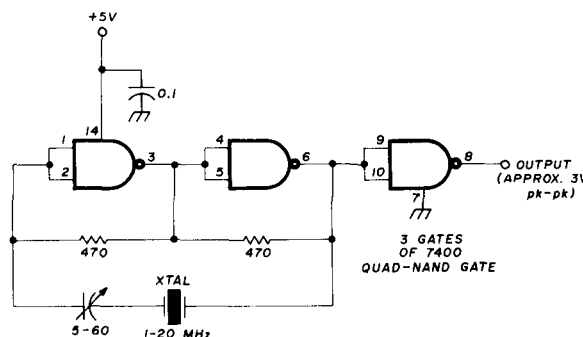


fig. 24. TTL crystal oscillator (after Weggeman, reference 13). Circuit overcomes poor crystal-starting problems and has a higher upper-frequency limit than the circuits of figs. 22 and 23.

other circuit functions for setting the frequency. In addition, it should not be possible for the crystal to oscillate on subharmonics of the overtone frequency, or on the fundamental. Reliable starting is also desirable.

The Miller oscillator, fig. 25, using an fet, has the advantage of requiring minimum components but doesn't give reliable starting performance. L1 can be

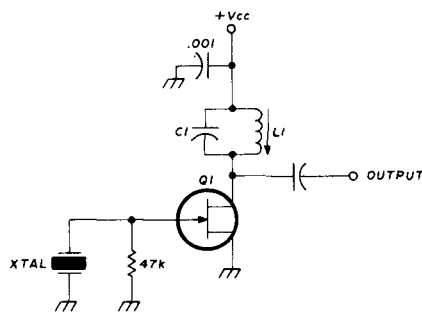


fig. 25. Miller overtone oscillator circuit. Not recommended because of problems with frequency instability due to output load variations and unreliable crystal-starting performance. L1-C1 is tuned to the overtone frequency. Q1 is a 2N3819, 2N5245, 2N5485, MPF102, MPF104-106, or T1588.

tuned to pull the crystal frequency but may not give enough range; output varies also. Apart from these difficulties, it's prone to oscillating on the fundamental or subharmonics of the overtone. Output load variations adversely affect the frequency. A simple circuit but not really recommended, as performance cannot be guaranteed.

The modified Colpitts overtone oscillator in fig. 26 is commonly encountered. Unlike the Miller circuit, reliable starting can be expected. It's suitable only for third-overtone crystals, as fifth-overtone crystals exhibit a much higher *esr*. Some third-overtone crystals having a high *esr* sometimes give trouble. Tuning L1 or varying the emitter resistor will pull the frequency, but output will vary. Feedback can be varied by changing C2. Harmonic output depends on the transistor used and the supply voltage. This circuit has the advantage of simplicity but is not recommended.

Fig. 27 illustrates a Pierce-type overtone oscillator. Note that a single-gate fet may be used. Crystal starting is sometimes unreliable and excess feedback may be

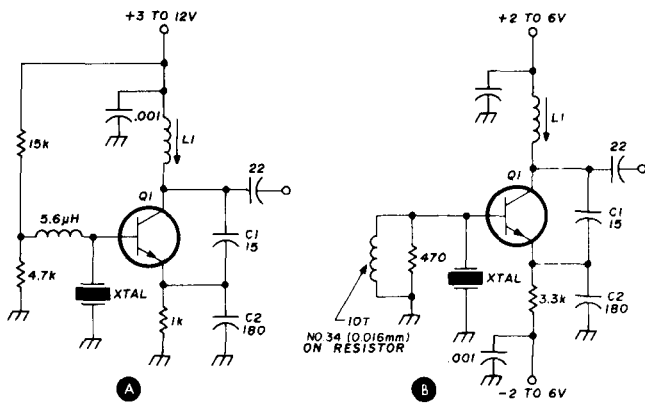


fig. 26. Third-overtone crystal oscillator for 20 to 60 MHz (A) and a minimum-component version (B). Although commonly seen in the literature, it's not recommended for reasons discussed in the text. L1-C1 is resonant at the overtone frequency. Q1 is a 2N3563, 2N3564, 2N5770, BF180, BF200 or SE1010.

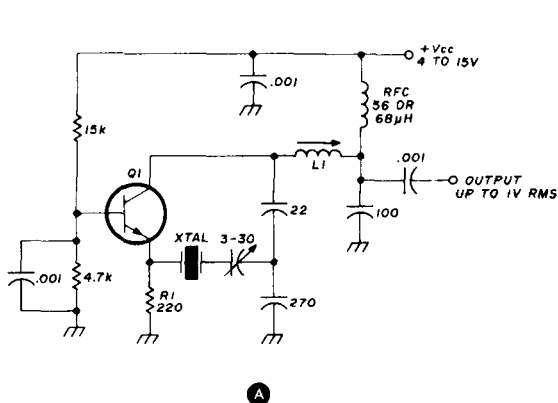


fig. 28. Third-overtone oscillator for 15 to 65 MHz (A) and a minimum-component version (B). All the desirable characteristics for this application are provided in this circuit. Crystal starting is reliable and crystal power dissipation is well below the allowable maximum. Q1 is a 2N918, 2N3563, 2N3564, 2N5770, BF180 or BF200. L1 resonates at the crystal frequency with 22 pF (1 μ H for 15 to 30 MHz; 0.5 μ H for 30 to 65 MHz).

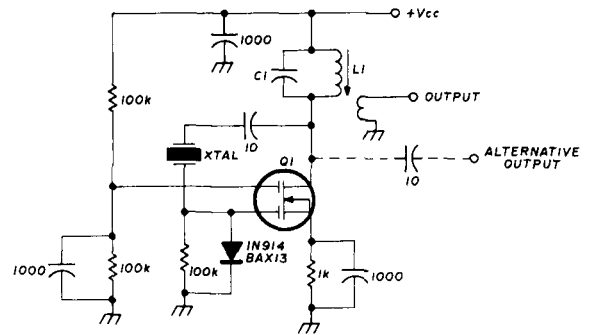


fig. 27. Pierce-type overtone oscillator for 15 to 60 MHz. Not recommended for the same reasons discussed in connection with the circuits of figs. 25 and 26 (see text). L1-C1 resonates to the crystal frequency. Q1 is a 3N200, 3N209, 40673, 40841, BF528, MPF121, MPF131, or equivalent.

required. No provision is made for setting frequency, but as in the previous two circuits, tuning L1 pulls the crystal. The comments on the circuits of figs. 25 and 26 also apply here.

When overtone crystal-oscillator circuits first appeared in the literature, they had a tendency to be somewhat complicated to avoid the problems discussed above. The following circuits are uncomplicated and reliable.

The circuit of fig. 28 provides all the desired characteristics with a minimum of components. Starting is reliable and crystal power dissipation is well below the allowable maximum. Increasing R1 increases crystal power dissipation. Stability is as good as that of a fundamental-frequency oscillator. This circuit is discussed in detail by Lane.⁶

Coil L1 can be roughly set to frequency with no supply voltage by shorting the crystal and dipping L1 with a grid-dip oscillator. Apply power, and while monitoring the output frequency, tune L1 close to the marked crystal frequency. Remove the short and trim the frequency with the 3 to 30 pF trimmer. Tuning L1 will pull the crystal, but L1 does not require tuning following the initial setup. Harmonic output is low, usually

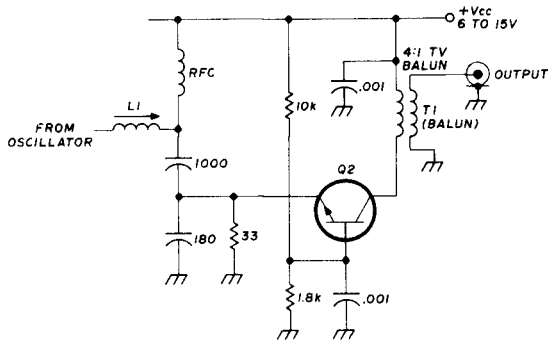


fig. 29. Buffer amplifier for the circuits of figs. 28 and 31. Circuit provides excellent performance and supplies several volts of output. Input and output tuned circuits must be well shielded. T1 is a 4:1 TV-type balun. Q2 is a 2N3563, 2N3564, 2N3646, 2N5770, BF180, or BF200.

around -40 dB, but depends on the transistor and the supply voltage.

A buffer is recommended. The circuit of fig. 29 is excellent, providing several volts of output. Output transformer T1 can be a standard 300- to 70-ohm vhf television balun or a homebrew balun. Alternatively, a single or double-tuned circuit can be used. L1 and the output tuned circuits must be well shielded and separated, otherwise instability may result. Q2 bias may need to be varied, depending on the transistor. Tune L1 for maximum output before trimming the crystal frequency. For multichannel operation, switching the crystal and trimmer is permissible, but leads must be kept very short.

The "impedance-inverting" circuit discussed by Foster and Rankin⁷ also has much to recommend it. This circuit is illustrated, for third-overtone crystals, in fig. 30. Performance is similar to the circuit of fig. 28. Coil L1 is used to trim the crystal frequency. The 560-ohm resistor across the crystal prevents oscillation on modes other than the overtone. This circuit readily adapts to a single-stage oscillator multiplier as we shall see later. It is more amenable to multichannel operation,

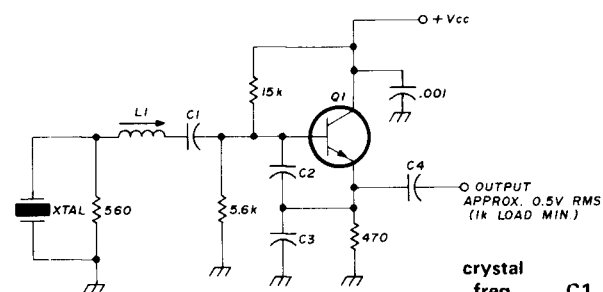
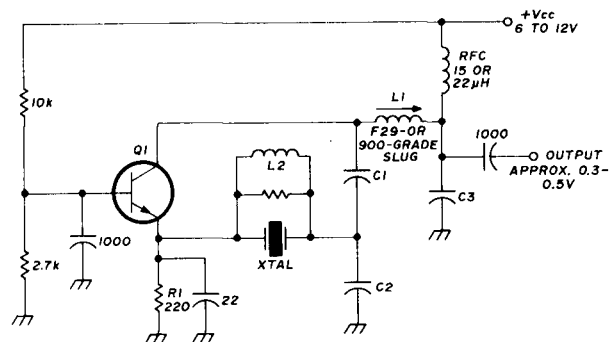


fig. 30. The "impedance inverting" circuit for third-overtone crystals in the 15 to 65 MHz range. Performance is similar to the circuit of fig. 28. Q1 is a 2N3563, 2N3564, 2N5770, BF180, BF200 or SE1010.

crystal freq (MHz)	C1 (pF)	C2 (pF)	C3 (pF)	C4 (pF)	L1
15-25	100	100	68	33	1/4" (6.5mm) diam form 12 turns no. 30 (0.25mm) closewound
25-55	100	68	47	33	15 turns no. 28 (0.3mm) closewound
50-65	68	33	15	22	10 turns no. 28 (0.3mm) closewound
					7 turns no. 28 (0.3mm) space to 1/4" (6.5mm) long closewound

as one side of the crystal is grounded. Note that if L1 is made too large oscillation on frequencies other than the overtone may occur.

Overtone crystals above 65 MHz are usually fifth- or seventh-overtone types. The circuit in fig. 31 is from Lane⁶ and is a variation of the circuit in fig. 28. The rf



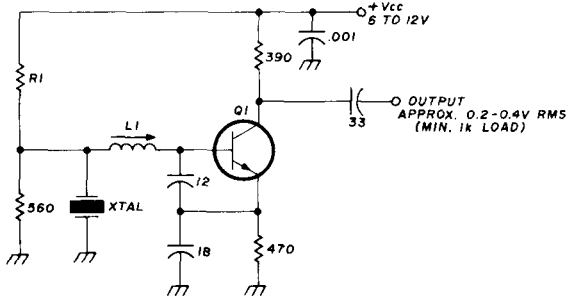
- L1 65-85 MHz: 7 turns no. 22 (0.6mm) or no. 24 (0.5mm) enamelled, closewound on 3/16" (5mm) diameter form
85-110 MHz: 4 turns no. 22 (0.6mm) or no. 24 (0.5mm) enamelled, on 3/16" (5mm) diameter form, turns spaced one wire diameter
- L2 10 turns no. 34 (0.2mm) closewound on low-value 1/4-watt resistor
- C1 65-85 MHz: 15 pF 85-110 MHz: 10 pF
C2 65-85 MHz: 150 pF 85-110 MHz: 100 pF
C3 65-85 MHz: 100 pF 85-110 MHz: 68 pF

fig. 31. Oscillator for fifth- or seventh-overtone crystals in the 65 to 110 MHz range. The buffer circuit of fig. 29 is recommended. Q1 is a 2N3563, 2N3564, 2N5770, BF180, BF200 or SE1010.

choke formed by L2, wound on a low value resistor, suppresses the lower resonances of the crystal, ensuring operation on the correct overtone. The comments on the circuit of fig. 28 also apply here. The buffer of fig. 29 is also recommended. The circuit in fig. 32 is a variation on the "impedance-inverting" oscillator from Foster and Rankin.⁷ Performance is similar to the circuit of fig. 31. Again, a buffer is recommended. The four circuits just described, figs. 28, 30, 31 and 32, are all slightly frequency sensitive to supply voltage variations, so a well-regulated supply is recommended.

The oscillator of fig. 30 can be readily adapted to a single-stage oscillator multiplier and has ready application in vhf converters. Good load isolation and low unwanted output levels are afforded by the circuit of fig. 33. The double-tuned circuit is the key to success here. Coils L2, L3 should be no more than critically coupled,

which results in the best output for good harmonic rejection. All outputs, other than the multiple of the crystal frequency, are about -60 dB or greater. Tuning L2 and L3 pulls the frequency slightly, but as this is usually a once-only adjustment, it is of little consequence. L2 has a broad tuning characteristic because of Q1 loading,

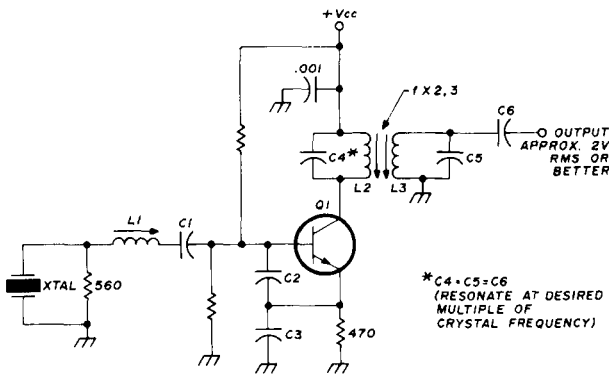


crystal freq (MHz)	L1	R1 (ohms)
60-85	7 turns spaced 1/4" long*	3300
80-110	4 turns spaced 1/4" long*	1800

*Wound on 3/16" (5mm) diameter form with vhf slug, no. 22 (0.6mm) enamelled wire

fig. 32. Another variation of the "impedance inverting" oscillator for 60 to 110 MHz fifth- or seventh-overtone crystals. Performance is similar to the circuit of fig. 30. Q1 is a 2N3563, 2N3564, 2N5770, BF180, BF200, or SE1010.

whereas L3 tunes quite sharply. The circuit is ideally suited to fet mixers having local-oscillator injection into the gate. A word of caution: the connection between Q1 collector and tuned circuit L2/C4 must be kept extremely short, otherwise parasitic oscillations will occur.



L2, L3 60-90 MHz: 9 turns no. 22 (0.6mm) enamelled wire, closewound on 3/16" (5mm) diameter form with vhf slug

90-130 MHz: 6 turns no. 22 (0.6mm) enamelled wire, closewound on 3/16" (5mm) diameter form with vhf slug

Coil forms for L1, L2 are spaced 0.6" (15mm) apart and assembly shielded.

fig. 33. Overtone oscillator-multiplier adapted from the circuit of fig. 30. This version is applicable to vhf converters. It provides good load isolation and low unwanted output levels (refer to fig. 30 for component values).

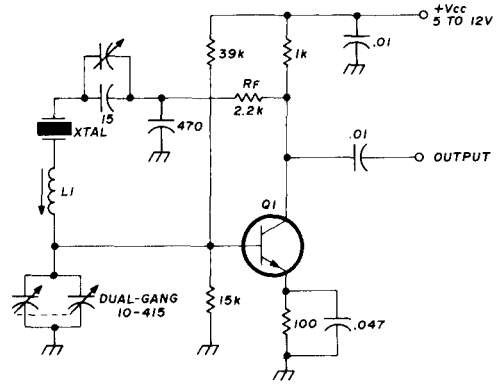


fig. 34. An extended-range vxo circuit (after Lane, reference 6). Maximum frequency shift is nearly 10 kHz at 5 MHz. Circuit is a variation of that in fig. 13, and the same comments apply (see text). Q1 is a 2N3563, 2N3564, 2N5770, BC107, BC547, BF115, BF180, SE1010 or equivalent.

variable crystal oscillators

This topic is well covered by Pat Hawker, G3VA,¹¹ and Lane.⁶ A recent article with useful discussions and practical details on this subject is by Doug DeMaw, W1CER;¹⁴ see also reference 15.

The greatest shift you can obtain from AT-cut fundamental-frequency crystals is about 1/500th of the crystal frequency. By far, one of the best circuits I've tried is

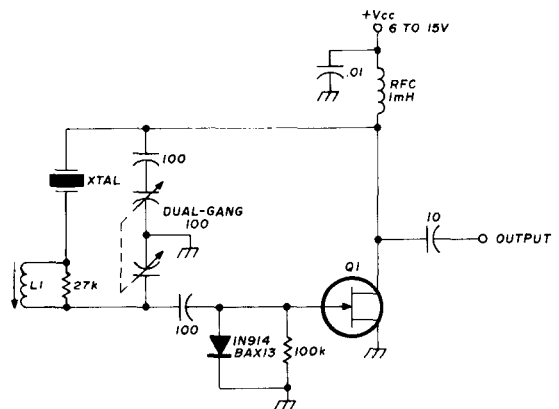
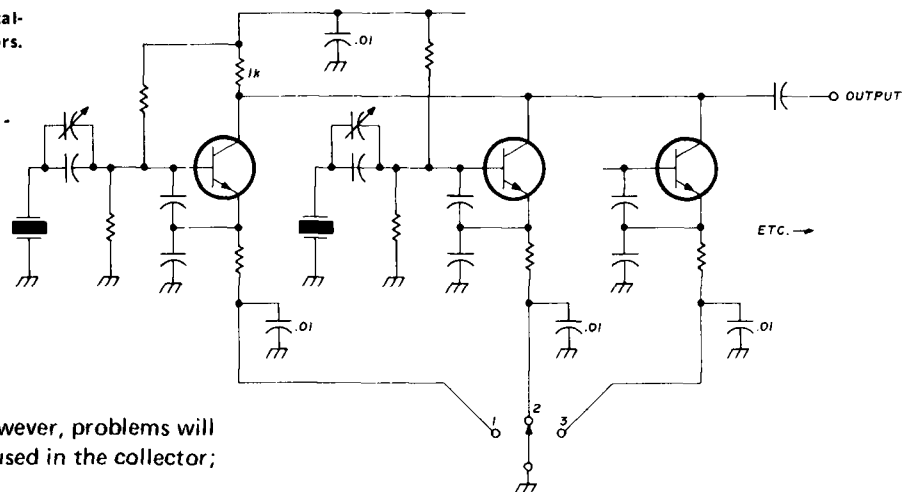


fig. 35. Vxo using a fet. Performance is similar to the circuit of fig. 34. A buffer is recommended for this circuit and that of fig. 34. L1 is a 30 to 80 μH slug-tuned coil. Q1 is a 2N3819, 2N5245, 2N5485, MPF102, MPF104-106, or TIS88.

that of fig. 34. It's described by Lane⁶ and is recommended. Frequency stability is not compromised greatly, even at the extremities of the shift. Using a crystal manufactured for vxo operation, the maximum shift obtained using this circuit approaches the maximum obtainable; i.e., nearly 10 kHz at 5 MHz. Harmonic output is high, as this circuit is a variation of that in fig. 13. Resistor R_f determines the feedback level and may have to be varied for best starting performance. Other

fig. 37. Another multichannel crystal-switching method using separate oscillators. Outputs are paralleled for dc and ac.



comments on fig. 13 apply here. However, problems will be experienced if a tuned circuit is used in the collector; the frequency shift is restricted.

The fet vxo in fig. 35 is commonly seen in the literature; this circuit is after DeMaw.¹⁴ He claims a similar shift to the circuit just discussed. In each case a buffer is recommended. (DeMaw also describes how to drive a tube grid from the buffer.)

No two crystals will be shifted by the same amount;

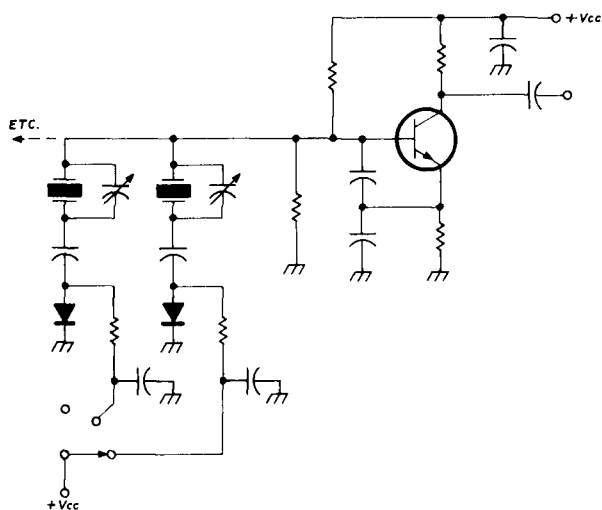


fig. 36. Diode-switching of a multichannel oscillator. Each crystal should be trimmed to frequency individually.

some provide more swing than others. Crystals especially manufactured for vxo operation are obtainable from some crystal manufacturers. Modern crystals perform well; FT243 crystals are generally poor. Those contemplating construction should read references 14 and 15.

Vxos should be built much the same as vfos to achieve best results. Don't use chassis-mounted crystal sockets. Mount the socket on insulating material to avoid stray capacitance. Better still, order crystals with flying leads rather than pins, and solder them directly into the circuit.

multichannel oscillators

In some applications, switching crystals to change frequency presents practical difficulties. Switching a dc circuit to make a frequency change is better and more convenient practice. Diode switching is one method (fig. 36). Each crystal should be individually trimmed. Difficulties do arise, as some crystals and oscillator circuits object to this method.

Another method is illustrated in fig. 37. Essentially it's a number of separate oscillators, each switched on in turn. Outputs are paralleled, both for dc and ac. If you want to switch crystals, circuits with one side of the crystal grounded are preferred.

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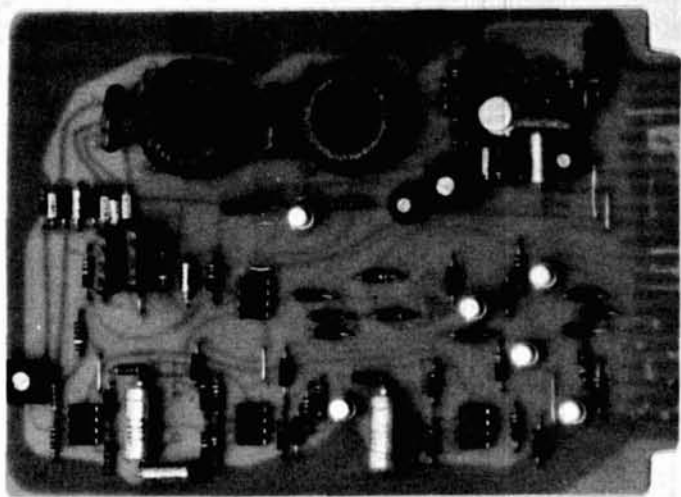
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The CATC systems approach to demodulator design, which was described in reference 1, was applied to the DT-500. Thus the unit is easy to build, simple to interface with other equipment, and is relatively inexpensive.

the DT-500

The circuits in the DT-500 are identical to those in the DT-600. The only differences between the two demodulators are those circuits in the DT-600 that were not included in the DT-500. (The reader is referred to reference 1 for circuit descriptions and adjustment procedures). The input bandpass filter, keying lowpass filter, ATC, and antispace circuits were included in the DT-600 to contend with peculiarities encountered on the high-frequency bands. Adjacent channel interference, noise, selective fading, and CW interference are not usual problems on the vhf bands; hence appropriate circuits for these problems were not included in the DT-500.

Audio from the station receiver is introduced into the DT-500 at a 500-ohm input (fig. 1). The 1000 ohm resistor, R2, is a current limiter, and the two silicon diodes protect the limiter stage from excessive audio voltage. All other parts of the circuit are identical to the corresponding circuits in the DT-600.

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The power supplies (± 12 volts and $+170$ volts) shown in reference 1 are also recommended for the DT-500. Several DT-500s and DT-600s may be operated from the same ± 12 -volt supply for increased cost effectiveness, but the regulator transistors should be replaced with IC regulators such as the LM 320-12 and the LM 340-12 to handle the required current.

The DT-500 can also function as an extremely low-cost beginner's model. Motor control and mark-hold features may be eliminated by omitting op amps U3, U4, U5, and Q5, Q6. These features account for more than 50% of the components in the unit. If you wish to eliminate these functions for now, they may be added later as operating convenience and budget dictate. If the

interfaces

As mentioned in reference 1, one of the prime concerns of the CATC-designed units is ease of interface with external equipment. Both the DT-500 and DT-600 provide open-collector outputs for data and control lines to interface with low voltage (particularly TTL) peripherals. It's possible to use the open-collector outputs to drive a machine interface and hence keep the high-voltage loop and keyer within the printer. This approach can increase the ease of interconnecting equipment (all interconnecting cables are at low voltage), and at the same time greatly reduce the noise generated by the high-voltage keyer and radiated by the loop. Two machine interfaces, the DI-50 and the DD-350, are

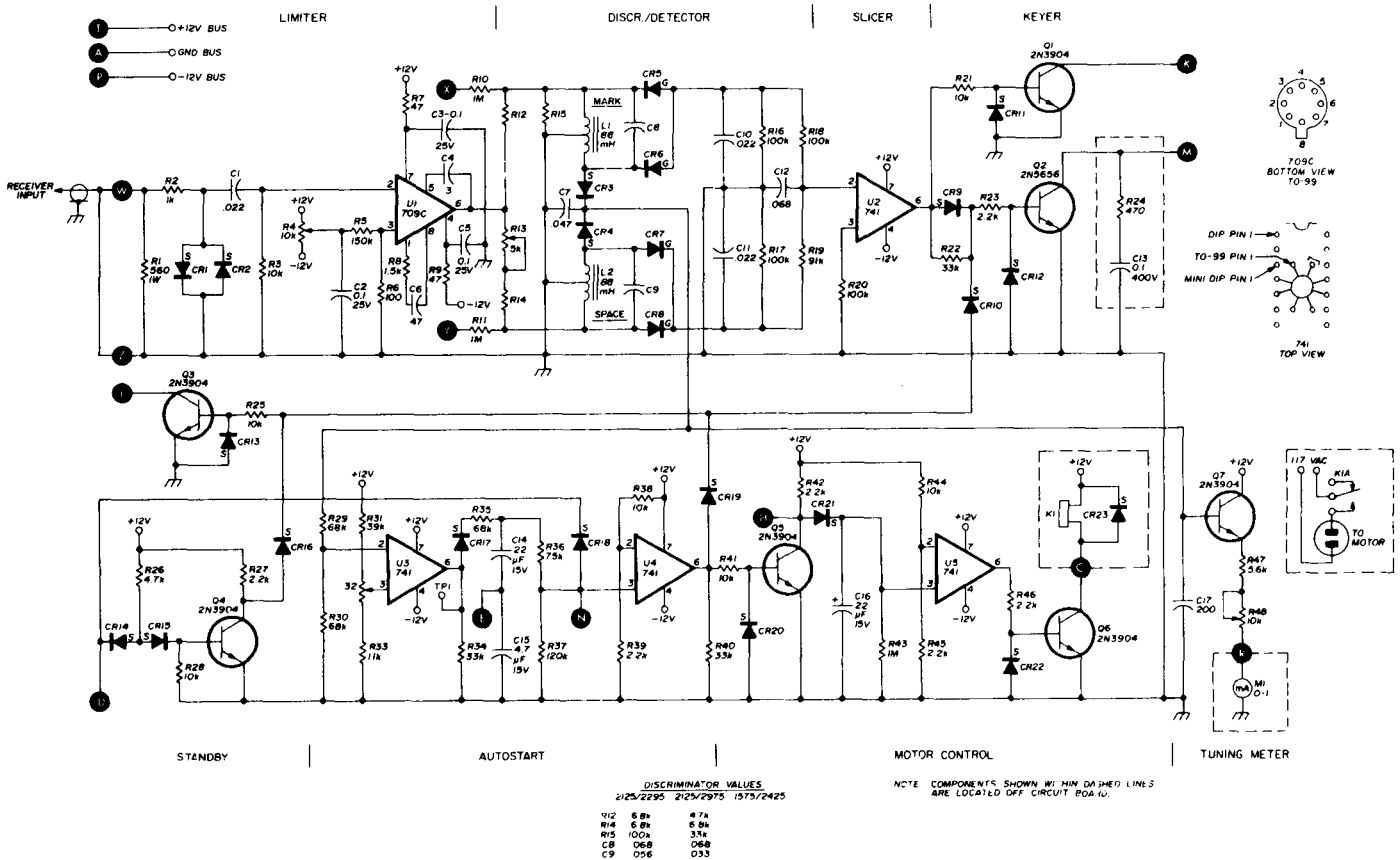


fig. 1. The DT-500 demodulator schematic. These circuits are identical to those in the DT-600 described in reference 1. The input bandpass filter, keying lowpass filter, ATC, and antispace circuits of the DT-600 have been omitted from the DT-500. Diodes marked with a G are germanium 1N270; diodes marked with an S are silicon 50 PIV unless otherwise noted.

bandpass input filter from the DT-600 were added (externally), the DT-500 would outperform the ST-3,⁴ ST-4, ST-5⁵ and ST-5A and would approach the performance of the ST-6 and DT-600.

As with the DT-600, the DT-500 is built on a single 6x4½-inch (152x114mm) board with a 22-pin edge connector. Fig. 2 shows board interconnections.*

*Double-sided circuit boards with plated-through holes are available from Data Technology Associates, Inc., Post Office Box 1912, Miami, Florida 33143. Send self-addressed, stamped envelope for information.

described here (a number of other interfaces, DI-30 logic-to-polar, DI-40 polar-to-logic, and a loop-to-logic interface have also been prepared).

DI-50 logic-to-loop interface. The DI-50 has its loop keyer floating (no ground in common with the logic portion of the circuitry) and hence may be inserted at any point in the selector-magnet loop. Fig. 3 is the schematic of the DI-50.

A logic zero at the base of Q4 causes Q4 to conduct

and supply current to the oscillator formed by Q1, Q2. The oscillator operates in the 800-kHz range. The 800-kHz energy is capacitively coupled (and hence decoupled for dc) through C4 and C5 to a bridge rectifier consisting of germanium diodes CR1-CR4. (As shown in fig. 4, the printer loop is in mark when a logic zero exists at the base of Q4 and in space with a logic

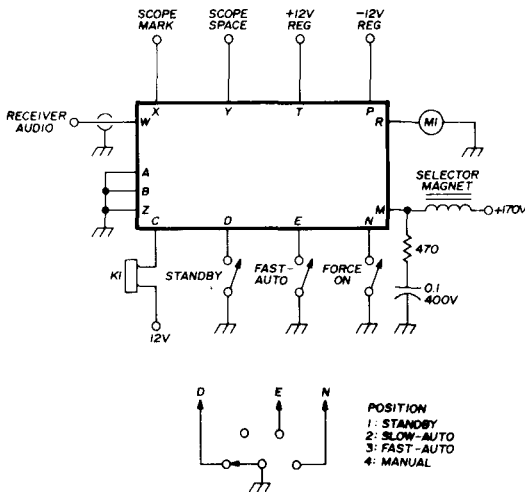


fig. 2. DT-500 demodulator board inter-connections (A) and an alternative circuit for a single switch (B). The unit is constructed on a single 6x4½-inch (152x114mm) circuit board with a 22-pin edge connector.

one.) The rectified output is filtered by C6 and applied to the base-emitter junction of Q3, biasing the transistor into the conducting state. The bridge consisting of CR5-CR8 ensures that the high side of the loop is returned to the collector of Q6 for either the DT-500 or

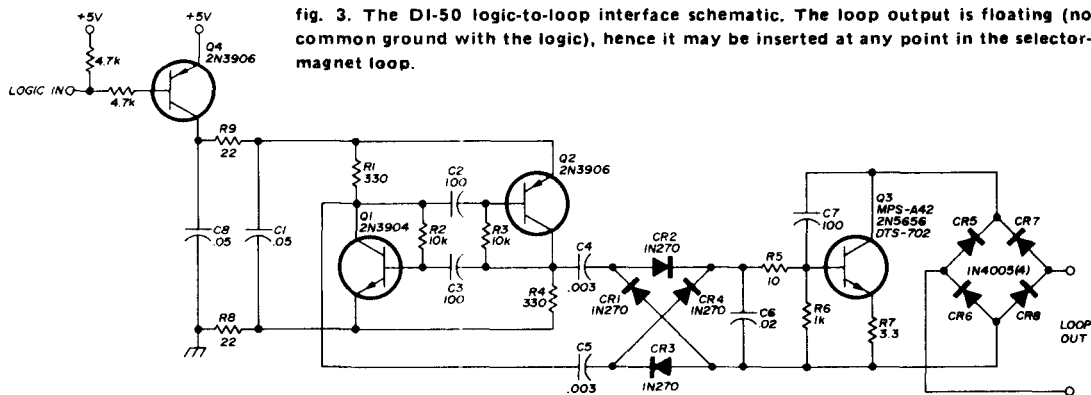


fig. 3. The DI-50 logic-to-loop interface schematic. The loop output is floating (no common ground with the logic), hence it may be inserted at any point in the selector-magnet loop.

connected to the collector of Q3 and that the low side is connected to the emitter, through R7.

If motor control is desired with the DI-50, one side of the coil of a 12-volt relay (K1 in fig. 1) is connected to the 12-volt supply, which in turn powers the 5-volt regulator for the DI-50. The other side of the coil is

DT-600 through a two-conductor shielded cable, the other conductor connecting the open collector of Q1 (either DT-500 or DT-600) to the DI-50 logic input.

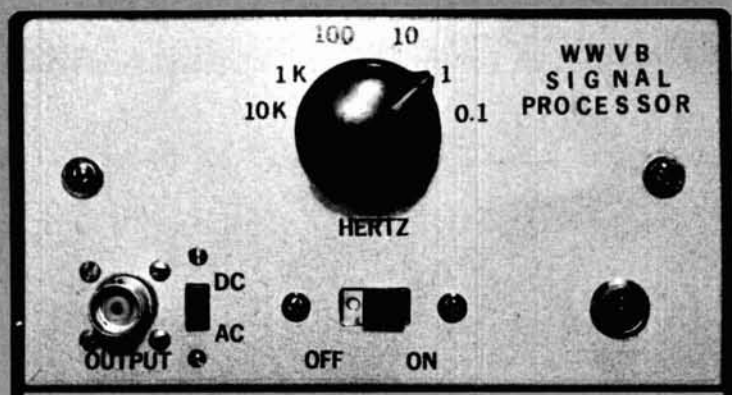
Q1 and Q2 should be a complementary pair such as the 2N3904 and 2N3906. Q4 could also be a 2N3906. Other components are not critical, but the low forward-voltage drop of the 1N270 is essential. Q3 should be a high-voltage transistor (300 volts) capable of 100 mA and 5 to 10 watts dissipation, such as the MPS-A42, 2N5656, or the DTS-702.

DD-350 selector magnet driver with motor control. The DD-350 (fig. 4) requires only a single-conductor shielded cable between the demodulator and the printer to control both the high-voltage keyer and the motor relay. Other features include a choice of input logic (mark = 0 or mark = 1) and open-loop operation during standby to reduce power consumption and heat.

Several optional input configurations may be implemented with U4C and U4D. If the mark output from the demodulator keyer (Q1 of DT-500 and DT-600) is a logic zero, as it is for the DT-500 and DT-600, then it is connected to H (fig. 4). However, data will not pass through U4D unless pin 13 is high. This condition may be accomplished by either connecting pin 13 to the positive supply through a 3.9k resistor, or by jumpering J1 and grounding either E or F. Then, either E or F may function as a disable terminal.

Suppose that the data (mark = 0) is connected to H, and F is grounded, enabling U4D. The data (mark = 0, space = 1) is inverted by U4D. A low (space) at pin 5 of the latch formed by U3A and U3B sets the latch (pin 6 high), which in turn enables U4A. The data passes through U4A and U4B. Pin 6 of U4B is high during mark, reverse-biasing CR1, allowing CR2 to conduct, and forward biasing Q1 (the high-voltage keyer). For space, pin 6 will be low, allowing current to flow through CR1 and removing the forward bias on Q1. At

the time the initial space set the U3A, U3B latch, it also set the latch made up of U3C and U3D and forced Q3 into conduction (discharging C2 and starting the timing cycle of U1). With U3C, U3D set, the high on pin 8 of U3C forward biases Q2, which pulls in the motor relay, starts the timing cycle of U2C, and discharges C5. As



WWVB signal processor

Link your
counter's time base
to the
super accurate signal
from the NBS station
at Boulder, Colorado

An increasing number of amateurs are using digital counters to determine transmitter frequency in the vhf and uhf region. This technique requires extremely accurate time-base frequencies if the readouts are to be meaningful. The low-cost frequency counters amateurs often use usually don't have accurate time-base crystal circuits; thus obtaining accurate readings with economy counters can be tedious. The time base must be monitored constantly against a primary frequency standard and warm-up time for ovens can be annoying. The answer is not to compare your counter time base with a primary standard but to use the primary standard itself as a time base by linking up with a Bureau of Standards station at Boulder, Colorado.¹

If WWV is selected, propagation delays will cause timing problems that affect accuracy. Station WWVB is a better choice. Its 60-kHz carrier ensures good accuracy and freedom from shortwave propagation delays. WWVB is the most powerful of the NBS stations (16 kW effective radiated power) and its timing signals are accurate to 2 parts in 10^{11} or better. WWVB's signal received in rural Wisconsin is solid night and day, season to season, except for a slight diurnal effect at local sunrise and sunset. WWVB's signal strength is $500 \mu\text{V}$ or more throughout the U.S. except for the upper East Coast, lower Florida, and northwestern Washington, where signal strength is $100 \mu\text{V}$.

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The following paragraphs explain how to amplify WWVB's 60-kHz carrier, eliminate the nonessential information on that carrier, and use the resultant output in conjunction with your frequency counter to obtain a precision frequency standard.

each second. Further clock information is provided by varying the length of time the carrier is reduced in amplitude each second. The carrier modulation is useless for the project described here and must be removed as it causes an accuracy problem with the final signal.

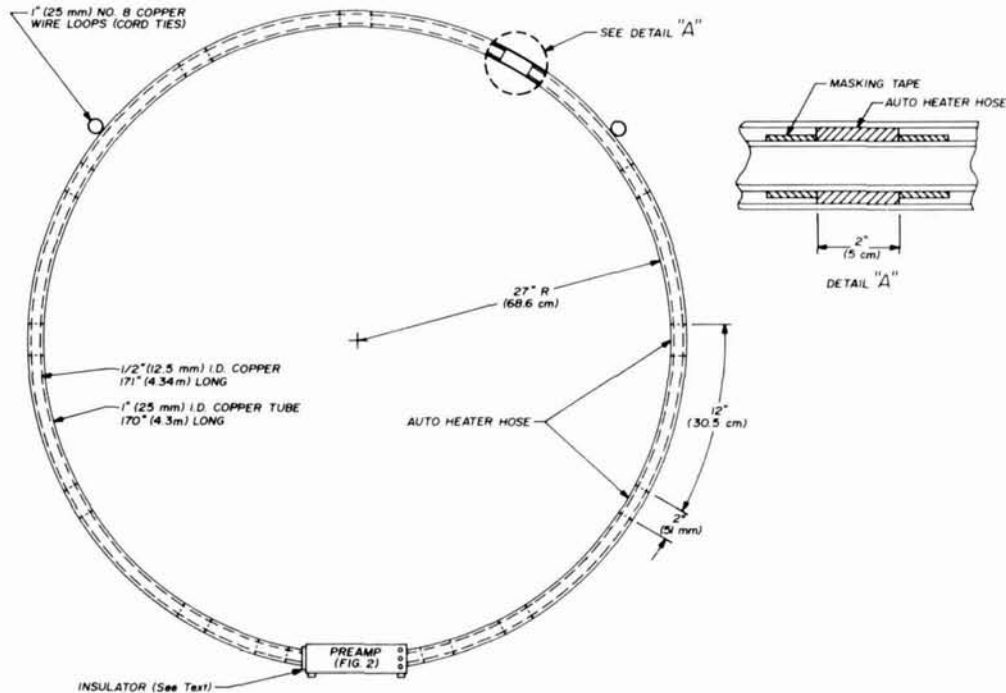


fig. 1. Loop antenna construction details.

preliminary checks

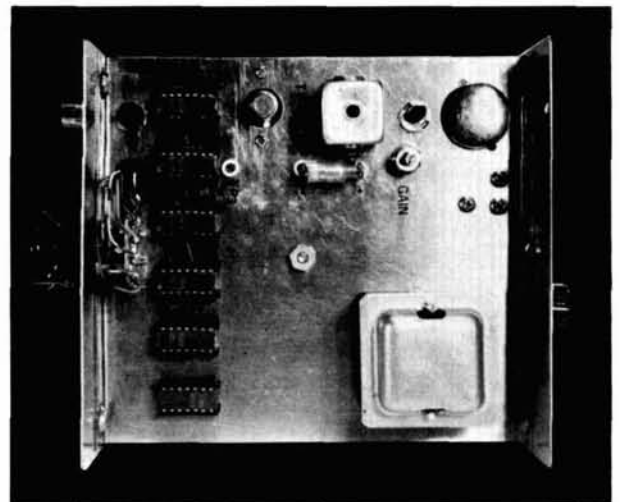
A test setup with receiver, loop antenna and 60-kHz preamp was built to determine the feasibility of this idea. I recommend building the loop and preamp first to determine if WWVB's signal strength is adequate at your location. The dimensions of the loop I built (fig. 1) were determined by the size of my attic opening. The large loop size accounted for the great success with WWVB reception. However, my attic location introduced some problems. The attic temperature range was 132°F (70°C), which severely detuned the uncompensated winding within the loop. Severe sensitivity and selectivity losses resulted. The loop now is in my basement, where temperature excursions are only 10°F (6°C) and reception is more than adequate.

The preamplifier (fig. 2) can be operated temporarily by connecting it to a 20-volt power supply capable of supplying at least 4 mA. Apply the 20 volts to J1 in series with a 1000-ohm, ½-watt resistor. After amplification by the loop preamp the signal is a pure 60-kHz sine wave and can be observed at test point 1 with an economy oscilloscope.

The modulation on WWVB's carrier is capable of controlling a sophisticated digital clock. This modulation is in the form of a 10-dB decrease in carrier strength once

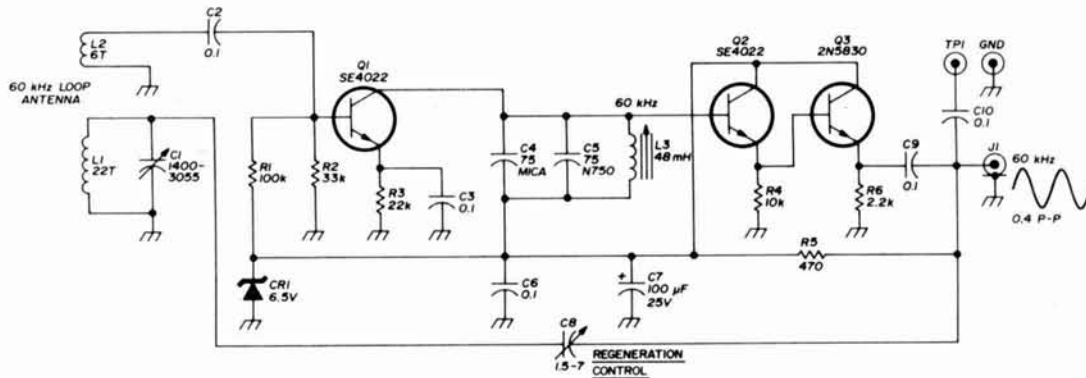
Another problem is caused by the fourth harmonic of the horizontal scanning amplifiers in local television sets. When operating on monochrome reception this signal is 15,750 Hz times four, or 63 kHz. Black and white is rare

Processor top view. Divider chain is immediately behind front panel switch. Rf amplifier, limiter, and zero-crossing detector are at upper left; power transformer is at right.



nowadays, but color broadcasts produce an interference frequency of 15,734.264 Hz times four, or 62.937 kHz. This signal beats with WWVB's carrier resulting in a 2.937-kHz beat note. The beat note is not pure because the interfering signals from television sets are rich in

information, a counter will count the frequency as more or less than 60,000. This phenomenon occurs because the squaring circuit turns on and off at a certain point on a sine wave. The squaring circuit turned on at a rising voltage of 0.6 and off at a falling voltage of 0.6. As



- L1 22 turns, part of loop antenna (see text)
- L2 6 turns, part of loop antenna (see text)

- L3 40 kHz remote control cup-core rf coil, 48 mH (found in many TV remote controls)

fig. 2. 60-kHz preamp that is installed in the loop antenna (fig. 1).

harmonics. There are two ways of eliminating this problem: providing 60-kHz receiver selectivity and careful placement of the loop antenna.

WWVB carrier-level shift

The WWVB 60-kHz signal was amplified to a level sufficient to operate a squaring circuit and TTL logic. The WWVB 10-dB carrier reduction, even though still of sufficient amplitude to operate TTL logic, created a new problem. At nearly every 10-dB carrier reduction a frequency shift occurred. If you count the number of cycles of the full-power carrier for one second, 60,000 will result. Also, if you count the frequency of the reduced-amplitude carrier, 60,000 will result. However, since the carrier power decreases every second, and the duration of the decrease varies in length to impart binary

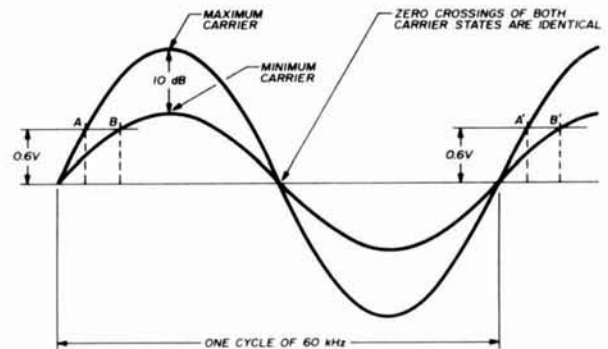
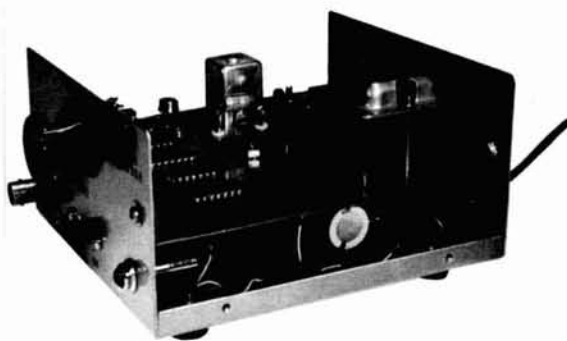


fig. 3. Apparent frequency shift of WWVB when using a digital logic circuit as a 60-kHz counter. The time for 1 Hz, as detected at the 0.6-V level, can be A to A', B to B', A to B', or B to A' depending on the carrier amplitude and the duration of its minimum level.

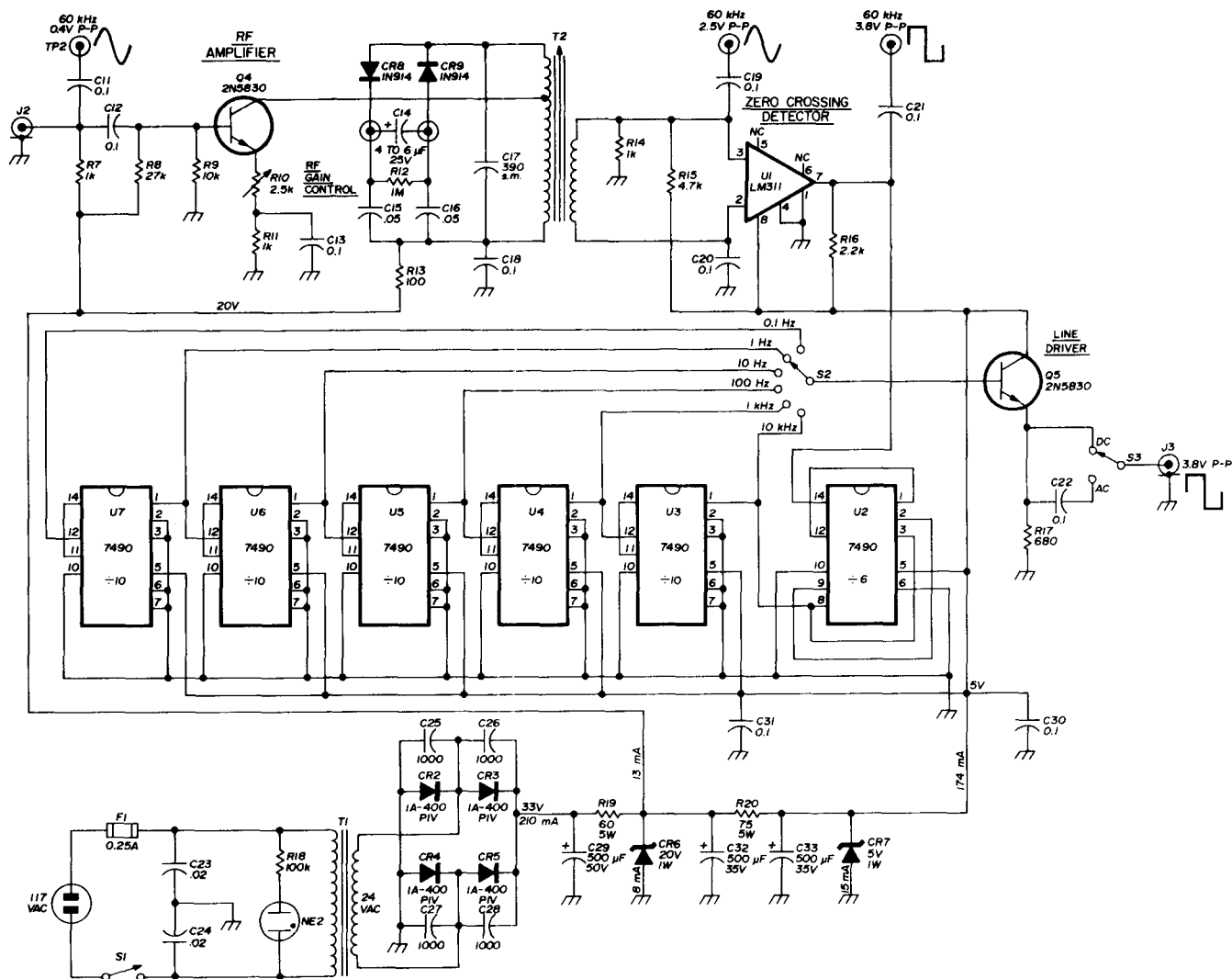
View of the WWVB processor showing part of the divider chain and power-supply wiring.



shown in fig. 3, 0.6 volt occurs at a different point in time depending on carrier power. Since the duration of the shift in carrier power is quite variable, the resulting frequency in the scheme also varied.

Simple and complex limiters were tried in an effort to eliminate the 10-dB carrier-level shift within the receiver. A Bishop limiter was both economical and very effective.² A scope observation of the limiter output showed no noticeable change in level, but the counted output showed a -138 to +12 Hz error. There had to be another way.

Further observation of the signal revealed an interesting fact: the zero crossings of the sine waves were always coincident, no matter what the amplitude. So why not count the zero crossings? A search for a suitable zero-crossing detector resulted in the trial of an operational



- C14 4 to 6 μ F, 25 V tantalum (low leakage)
- T1 24 volt, 500 mA power transformer

- T2 40 kHz remote control cup-core rf transformer, slug tuned. Total primary inductance, 7.5 to 46 mH, tapped up 0.5 mH; secondary, 20 μ H (found in many TV remote controls)

fig. 4. Schematic of rf amplifier, limiter, zero crossing detector, divider chain and power supply.

amplifier. It was a fair detector but its output was not a usable square wave, because op amps are too slow when used in this type of service. An LM311 comparator (fig. 4) was tried with great results; the output was a beautiful square wave. Removal of the limiter further proved that the LM311 was a true zero-crossing detector. (The limiter was retained in the final circuit, however, to correct for possible fading and lightning static.) You'll need a scope with good low- and high-frequency response to observe the square waves within the processor.

Now that we have an accurate and usable 60-kHz square wave, it must be divided down for use as a gate for a counter. A 7490 counter IC connected in a divide-by-six configuration provides a 10-kHz square wave. Five more type 7490 ICs connected as divide-by-ten circuits provide 1-kHz, 100-Hz, 10-Hz, 1-Hz and 0.1-Hz outputs. If your counter has a MacLeish count gate and control

logic, you can eliminate one divide-by-ten circuit or switch it out with S2.³

The last division by ten is done within your counter by a very necessary multiple-function stage that can't be eliminated. The elimination of one 7490 stage will decrease the 5-volt circuit current by 27 mA, and to maintain 5-volt zener current you'll have to increase R20 to 93 ohms at 5 watts and R19 to 71 ohms at 5 watts (fig. 4). You may decide, however, to retain the 7490 stage if you want to use the processor for tasks other than gating a counter; after all, 7490s no longer cost \$16.00 each! If your counter uses RTL logic in its divider chain (MC790 etc.), it will be necessary to use an interface device. An npn silicon transistor connected as in fig. 6 will act as a buffer between the 5- and 3.6-volt systems.

A phone jack with an spst switch attached must be

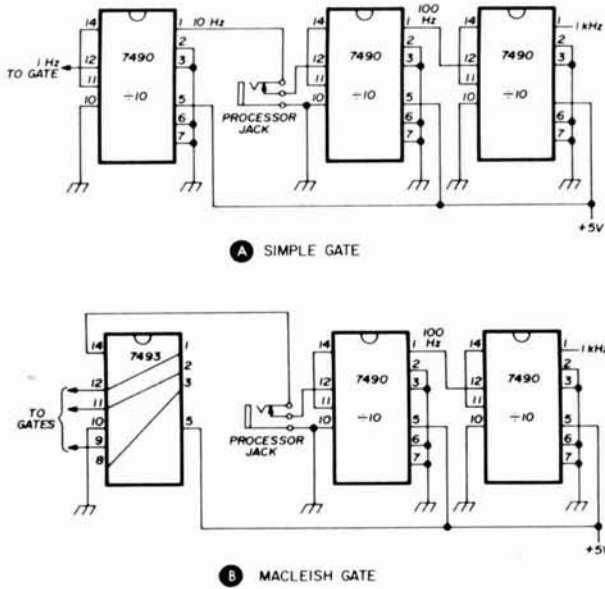
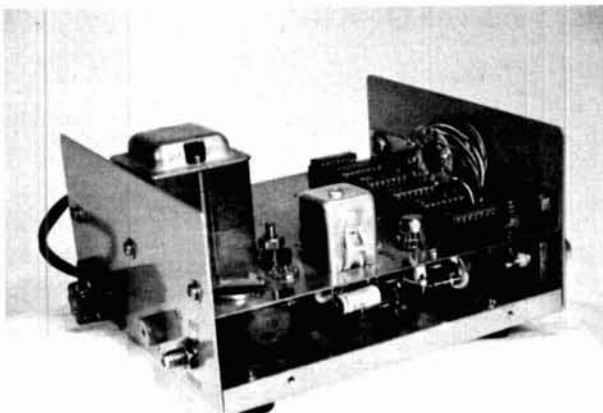


fig. 5. Modification of the two most popular counter crystal oscillator divider chain circuits to accommodate a processor jack.

mounted at the rear of your counter. Connect it as shown in figs. 5 or 6. Those who have built counters will have no qualms about drilling holes, and those with manufactured counters should have no worries either if their work is skillfully done; it's the botched-up appearance of electronic equipment that hurts its resale value!

When the plug from the processor is inserted into the counter, the crystal-oscillator divider chain is interrupted and the processed WWVB signal gates the counter. If the processor output is set at one second, and the counter input is connected to the 60-kHz square wave at test point 4, 60,000 Hz will appear on the counter readout. This is a great test for the health of your counter's gating circuit. Now pull out the plug, allowing your counter to run on its own time base. The readout probably will not be exactly 60,000 Hz at that time.

Left side of WWVB processor showing T2 and LM311 comparator.



Many loop designs are available.^{4,5} I chose the one most difficult to build: the double copper shielded type that has immunity to capacitively coupled noise. However, a large loop wound on a simple wooden frame, popular with the broadcast radios of the 1920s, would be fine. A long ferrite loopstick was also tried; it worked but required more gain in the preamp.

Construction details are shown in fig. 1. Obtain two pieces of soft copper tubing at a plumbing supply store. One piece should be 1/2 inch (12.7mm) ID by 171 inches (4.34m) long. The other, 1 inch (2.5cm) ID by 170 inches (4.3m) long. Before bending into a circle with a 27-inch (70cm) radius, the smaller-diameter tube must be inserted into the larger tube. The small tubing must touch the outer tube at only one spot: the entrance to the preamp box. To prevent a short between the tubes anywhere within the circle, the inner tube is suspended within the outer by liberal use of short lengths of automobile heater hose.

Pieces of hose 2 inches (5cm) long are secured at both

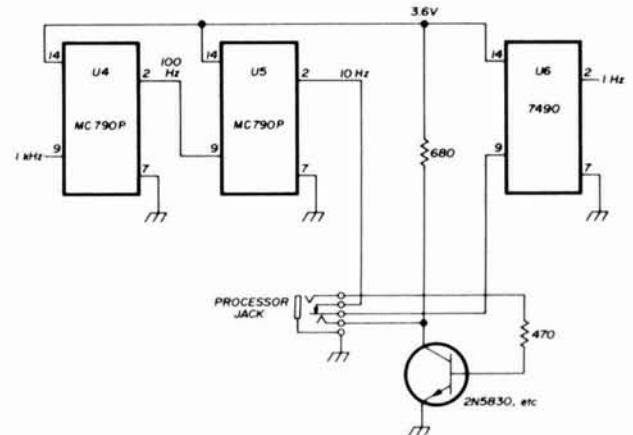


fig. 6. Interface circuit for use between WWVB processor and digital counters having RTL logic.

ends with masking tape to prevent migration from their 12-inch (30cm) intervals during insertion into the larger tube. After carefully forming into a 54-inch (1.4m) diameter circle, you will have to position the inner tube with a mallet. Easy does it! One end should protrude 3/4 inch (17mm), the other 1/4 inch (6mm).

The end with the shortest protrusion is inserted 5/8 inch (15.8mm) into a 1-1/8-inch (29mm) hole punched into one end of the preamp box (see fig. 7). The other end is inserted into a 1-3/8-inch (35mm) hole at the opposite end of the preamp box. This end is insulated by two blocks of fiberglass, formica, or bakelite. The other end is sweat-soldered to the zinc-plated steel box. For this you'll need a torch or a very large soldering iron because the copper is a great heatsink. The inner and outer tubes are connected together at this point with a copper washer soldered in place. Install the insulators after everything cools down. Two large terminal strips with a minimum of 52 lugs total are bolted to the sides of the preamp box.

A 190-inch (4.8m) length of 50-conductor telephone cable was used as the loop inductance. This cable, which is used to connect phones in business offices, seems to be available in short lengths as scrap everywhere. Forty-four of the conductors were connected in series using the terminal lugs within the preamp box. The remaining six conductors were connected in series and used as a low-impedance tertiary winding to couple the high-impedance loop to the low-impedance preamp input. Use care as you connect the cable in series. Use an ohmmeter and observe the cable color coding. One shorted turn can render the loop completely useless.

Forty-four turns of wire resulted in too much inductance, as the coil was easily tuned down as far as 30 kHz. The winding was split in half and both halves paralleled, which resulted in 22 turns of 2.275 mH inductance with a dc resistance of 4.4 ohms. The stray capacitance and a 2500 pF trimmer tuned it to 60 kHz.

final assembly

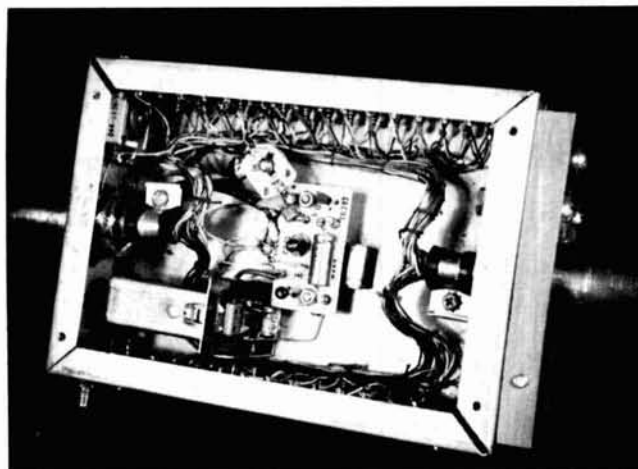
The amplifier components, circuit board, test jacks, coax connector and loop trimmer may now be mounted. The finished loop will stand alone, supported by the preamp box. Two wire loops are soldered to the upper part of the loop so that cords can be attached to prevent it from falling over if accidentally bumped. The processor and the power supply for the entire system are mounted in a 5-1/4 by 3 by 5-7/8-inch (13.3 by 7.6 by 15cm) equipment cabinet.

The hand-wired circuit layout isn't critical. Three convenient test-point jacks make testing and tuneup easy. The limiter time delay capacitor is mounted on plugs so it can be disconnected during alignment. The 1000-pF disc capacitors, C25, C26, C27, C28 eliminate diode radiation into local vhf receivers. To be 100% effective, these capacitors must be soldered to the diodes with as short a lead length as possible.

tuneup

After a thorough wiring check connect the preamp and processor with a length of coaxial cable. Any small-diameter coax can be used. This cable also supplies the 10 volts dc for the preamp. Power supply regulation is important. The 10-dB carrier swing and logic dividers tend to modulate the dc supply and may cause a problem in another stage. So be sure that the zener diodes are truly clamped at 5 and 20 volts and that their power dissipation is not approached or exceeded. This can come about because of the wide range in power transformer outputs available to builders.

Signal generators for 60 kHz aren't readily available, so a portable television set may be used as a temporary signal source. Place the television set, which is receiving a clean signal from any local channel, near the 60-kHz loop. Attach an oscilloscope to test point 1 and set its time base to the range that includes 10 to 30 kHz. Tune the loop trimmer and the slug in L3 until a sine wave trace appears. If everything is working well, you are now tuned to about 63 kHz, the fourth harmonic of the television horizontal scanning frequency. The third and fifth

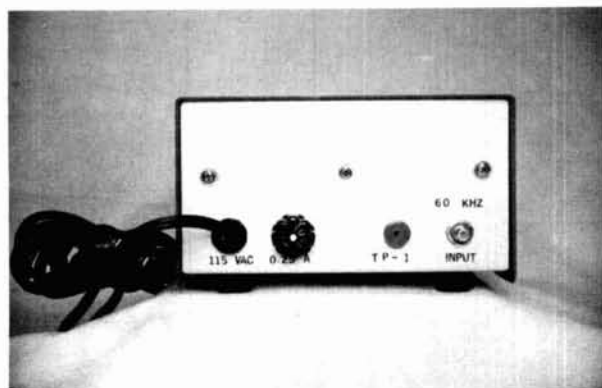


Underside of preamp. Terminal lugs are used to series connect a 50-conductor telephone cable, which is used as the loop inductance.

harmonics must be avoided. It is sometimes possible to tune homemade loops to 46.65 or 78.75 kHz by accident. If the television set is too close the system may overload as you tune to resonance. It's wise to keep moving the television set farther away as the scope trace increases. Rotating the loop to a partial null is also helpful.

Now turn the television set off. If the loop is oriented for maximum signal from Boulder, Colorado, you should see a weak sine wave with its characteristic one-second dip in amplitude on the screen. Don't forget you're tuned about 3 kHz too high in frequency. Now retune the loop and L3 for maximum using WWVB as a signal source. If the sine wave does not have the one-second dip, one or both of two things are happening. First, there may be a television operating close by — maybe a neighbor's set. Second, the preamp may be oscillating. If the latter is the case, readjust regeneration capacitor C8 until the signal is reduced to the point where the one-second flutter starts. If the preamp continues to oscillate, reverse the tertiary loop winding. The trace, on a well-focused scope, should be a fine single line writing a 60-kHz sine wave. A fuzzy line wider than normal indicates interference from a local television set.

Rear of processor.



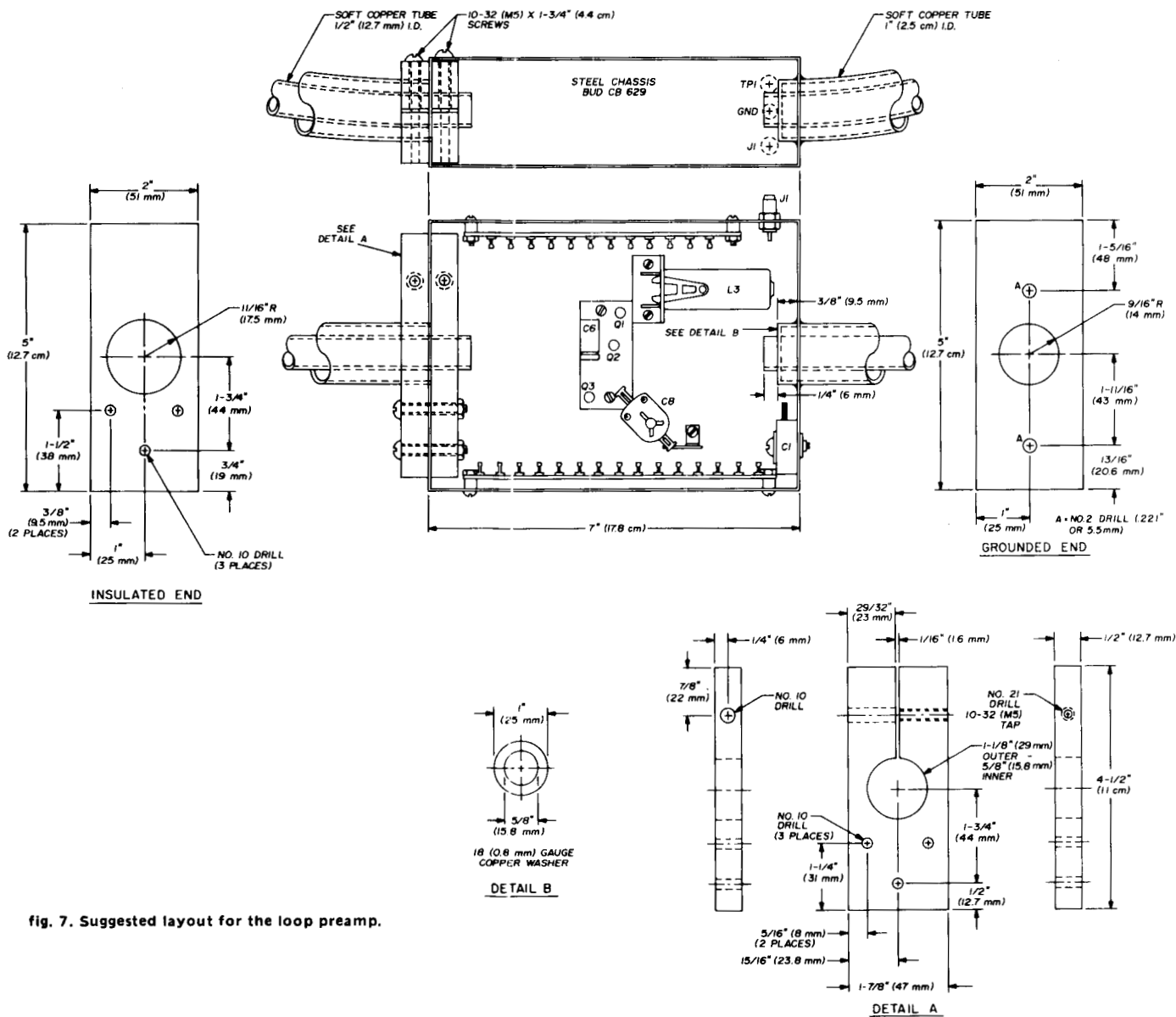


fig. 7. Suggested layout for the loop preamp.

Repositioning the loop so that the interference is at a null while WWVB's signal is maximum is quite successful. I can coexist with the local color television set even though it's only 30 feet (9m) away. System selectivity allows me to live with local television interference. Better than 3-kHz selectivity is not too hard to obtain with three tuned stages at 60 kHz. This will be quite evident when transformer T1 is resonated. Attach the scope to test point 3 and remove time delay capacitor C14. Tune the slug in T1 for maximum. (This is a little difficult because of the one-second flutter.) You only have a second, but it can be done with a little practice. Adjust the gain control at this point for a maximum undistorted sine wave. Reconnect time delay capacitor C14, and within four to six seconds the sine-wave flutter will stop, indicating successful limiter operation.

If your efforts have been successful, you now have a

source of accurate timing intervals and frequencies. Although the original intent was to build an accurate time base, the instrument's output may be multiplied for use as a local frequency standard. A 1-MHz output is easily obtained with solid-state multipliers.

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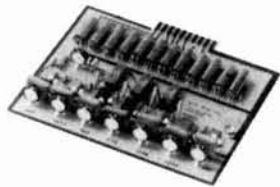


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high-speed divide-by-n counters

What to expect
in available TTL logic
for application in
two-meter
frequency synthesizers

Many articles in the amateur magazines have described frequency synthesizers for use in two-meter fm transceivers. Most generate a harmonic of a crystal-controlled reference frequency by a voltage-tuned oscillator (VTO or VCO) locked to the proper frequency by a programmable frequency divider (divide-by-n counter) and a device that provides a control voltage proportional to the phase difference between the divided-down signal and the reference frequency. The voltage is amplified and used to tune the oscillator to the right spot.

The reference frequency is made equal to the desired channel spacing. For instance, 146.94 MHz is the 4898th harmonic of 30 kHz. If we had a divide-by-4898 circuit and an accurate 30-kHz reference frequency, no great

problem would exist in making a stable exciter for an fm transmitter. If we had a switch to make the reference-frequency harmonic anything we wanted between 4867 and 4933, we could do business on any of those fm channels. One difficulty is that such counters (those made from low-priced parts) don't work at very high frequencies. This article describes a counter that goes about as high as possible — at least for fifteen dollars' worth of ICs. It also explains why you can't go higher.

presettable counter IC specifications

In the manufacturers' applications notes I've seen, the highest frequency quoted was 25 MHz for a device with a specified test at 8 MHz. Other literature quotes 22 and 13.5 MHz for input frequencies to the programmable counter portion. However, the Hewlett-Packard HP-8660A synthesized signal generator uses several preset counters operating in the 20- to 30-MHz region. I made a partial copy of the instruction-book circuit. The HP-8660A uses 8290s and 74H logic; I used SN74196s (which were listed in the surplus ads) and Schottky-clamped 74S logic, which I had on hand. It turned out that both were faster than those used in the original.

circuit description

The logic diagram of my circuit is shown in fig. 1. For a three-stage version merely leave off the last decade; maximum frequency remains the same. Details of the first two stages are shown in fig. 1. The counters are preset to, say, 5555. Following the load pulse, which is negative-going on a line that's normally high, the input frequency is counted until the count gets to 9997 (the terminal count). The next clock pulse triggers the auxiliary flip-flop, again enabling the load pulse (two cycles long), getting us back to zero. The total count is 10,000 minus 5555, or 4445 (10-kHz output for 44.5-MHz input).

First I tried the parts barefoot (partially wired in) to make sure they were as advertised. The SN74S112 went

By Hank Cross, W1OOP, 111 Birds Hill Avenue, Needham, Massachusetts 02192

up to 160 MHz in a simple divide-by-two setup. The SN74196s operated as decade counters (the data input pins 3, 4, 10 and 11 grounded) went up to 70 MHz — no problem.

To find out if the unit is working correctly requires enough precision to spot one missing pulse in 10,000. I used either a digital synthesizer or a signal generator and counter for the input signal (-1 to plus 13 dBm sine wave worked okay) and a counter on the output. And of course a calculator is needed. (Lots of digits blinking around.) I found that the divide-by-4445 unit first became a divide-by-4447 then a divide-by-4450 counter as the input frequency was increased until the first-bit de-

how to go fast

To make a presettable counter (either up or down counter) work at high frequency we must do two things:

1. Recognize the terminal count and set up the flip-flop before the next cycle of the input frequency.
2. Make a load pulse long enough to ensure that all counters are preset to the right number and the transients have died out. For the SN74196, the book specifies 20 ns; mine was 30 ns at 55 MHz.

To recognize the terminal count, 9997, we look for a 7 in the first decade (0111) and nines (1001) in the rest.

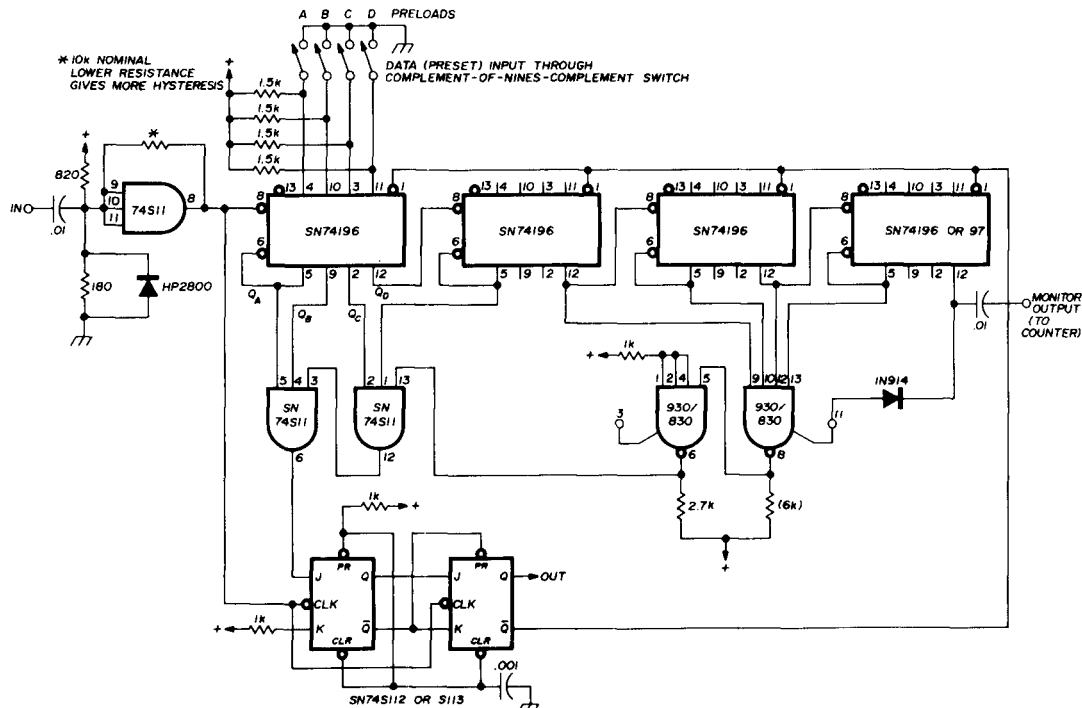


fig. 1. High-speed four-decade presettable counter. "Out" pulse (positive) is 30 ns long at 55 MHz. "Monitor" pulse is 20% duty cycle at about 10 kHz. Input is -1 to +13 dBm sine wave.

coding wasn't quite fast enough. The 3- and 4-decade versions had about the same maximum count frequency, so I wouldn't expect trouble from adding a fifth decade. One SN74196/8290 (so marked) lost counts when used in the first stage above 28 MHz, but it worked okay in the third. The TI SN74196s went to 56,451.5 with the right numbers. I borrowed some Signetics 82S90s; with these in the first three stages the maximum frequency was 60.89 MHz but was 56 MHz with only one (in the first stage).

There will be some problems at other values of preset, but so far I haven't investigated them, as I haven't figured out how to make 10,000 tests quickly. When the VCO loop is complete and the switch is wired in I'll go looking for trouble. Either the counter reads the same number as the switch or it doesn't.

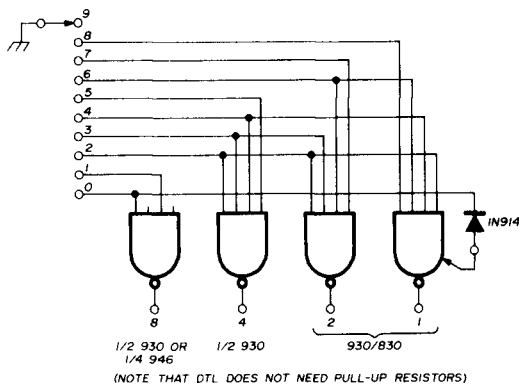
Both 7 and 15 have the three-ones pattern in the first three binaries; but an SN74196 does not count to 15, and in any case it would get to 7 first because it's an up counter. The same is true for a 9; two ones are enough to decode a 9. The pattern fills in from the right: the last decade hits 9, then the next, and the next. Four counts later Q_C of the first decade is 1; on the sixth count Q_B is a 1; and one count later the Q_A terminal goes high, about 10 ns later than the input clock's down-going transition. (Both the SN74196 and the SN74S112 work on the negative-going edge of the clock pulse — here it's pretty much a sine wave.)

The best choice for fast action is an SN74S11 positive-AND gate, which gives positive output for all-positive inputs. The pulse, delayed another 4.5 ns by the gate, is applied to the J input of the SN74S112/113/114

dual flip-flop. The specified setup time (J positive before clock transition) is 3 ns, so the total is 17.5 ns, a full cycle at 57 MHz. (The numbers seem to check out.)

Compared with the Q_A output we have an extra 17 ns at Q_B and 52 ns at Q_C , to say nothing of 122 ns for the Q_A of the second decade; so there is only one critical time delay here. If we had used 8 instead of 7 there would have been more problems. A 930 DTL gate does very well for the other decades (see fig. 1).

If the gates enable the J input in good time, the SN74S112 toggles on clock number 9998. Q goes up and



DIVIDE BY DIGIT	PRESET (BCD)	1	2	4	8
0	9	1	0	0	1
1	8	0	0	0	1
2	7	1	1	1	0
3	6	0	1	1	0
4	5	1	0	1	0
5	4	0	0	1	0
6	3	1	1	0	0
7	2	0	1	0	0
8	1	1	0	0	0
9	0	0	0	0	0

fig. 2. Nines-complement encoder (one decade; NAND gates used as NORs). The first decade should be tens complement (preset 6 for 4, not 5), which is easily done by a wiring change at left.

\bar{Q} down, working the set (PR) input of the second section, so *its* \bar{Q} goes down. This output is the load input of all four decades. On count 9999 the first section returns to normal. On count 0000 the second section returns to normal, ending the load pulse. At 57 MHz this is two periods (35 ns) less 5 (the extra time for the direct set to work), or 30 ns. The load pulse extends into the first count period by 5 ns, but this doesn't seem to make any difference.

some device advice

My experience with available devices used in high-speed counters is presented below for those interested in what to expect. The TI SN74196, Motorola MC4016, and TI SN74192 are examined.

Up counters are easier to decode and are more difficult to preset than down counters such as the MC4016 and SN74192. The SN74196 presents some problems. Preset coding is by nines-complement (9 minus the desired number). The best switch to use is called

"complement-of-nines-complement," but these seem hard to come by. For a few digits, an encoder from 10-point to nines complement (or any other code) can be made with four gates per decade using two 930s, as in fig. 2. A BCD nines-complement converter can also be made using gates, inverters, and an exclusive-OR per decade.

The SN74196 uses external terminal-count decoding and the counters are nonsynchronous. On the other hand, it operates as a preset counter beyond 50 MHz.

The MC4016, designated as a divide-by-n down counter, has other problems. It costs as much as an 82S90. Its Q_A delay, although not specified, is about 20 ns. Its Q_B delay is high, and its built-in zeros detector is not usable in the first decade. Its maximum frequency is probably less than 35 MHz with all possible circuit tricks employed. Early decoding should probably be done on "4." Three flip-flops would be required.

The most popular down counter is the SN74192. Its price is right; a BCD or (preferably) a BCD-complement switch presets it; it has built-in terminal count decoding ("borrow"); and the counters are quasi-synchronous. Time delay at the Q outputs is specified, although delay is longer for a 1-0 transition.

BCD down counting means that either the first bit goes high or zero, or that two bits change together, which involves a 1-0 change thus limiting decoding speed. Minimum decoding delay of the SN74192 is about twice that of the SN74196. So the maximum frequency of the SN74192, based on book data, would probably be no more than 28 MHz; however, I haven't made any circuit measurements in this regard.

construction

I made tests on a circuit wired on a 3677-2 Vector board. This board costs more than the ICs, with its socket. I used Cambion sockets for ease in swapping counters. The Vector board has 1/4-inch (6mm) wide strips for B+ and ground. I used several CS13 tantalum-slug bypass capacitors between the two buses at strategic points. Wiring was no. 22 (0.6mm) solid hookup wire. I found no layout or grounding problems. All unused inputs were connected to V_{CC} through a 1k resistor. You'll never find out what's going on without a high-speed dual-trace scope; however, once it's going, you're all set.

The input circuit in fig. 1 worked better than several fancier "trigger" circuits. Note that a resistor between the input and output of an SN74S11 provides positive feedback. Without the resistor the circuit may oscillate with no input signal; adding positive dc feedback makes it a trigger with hysteresis. The whole counter draws less than 300 mA at 5 volts.

Something that hits 10-kHz multiples at 48 MHz has obvious application on two meters. That's the next step.

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superfluous signals

On-the-air
tune up is
becoming more frequent.
These ideas
will help you
avoid this illegal practice

Amateurs have recently increased the practice of tuning up on the air, which has reached such a level that it's often impossible to work a DX station or participate in a net. Many tune-up signals are weak, but others are far stronger than the desired signal. Such practices are not only annoying, they're also illegal. An excerpt from the International Telecommunications Union regulations (693) states in part "*All stations are forbidden to carry out . . . unnecessary transmissions . . . the transmission of superfluous signals and correspondence . . . (and) the transmission of signals without identification.*"

Observation and inquiry show that three factors are involved in the development of on-the-air tune up practices: the characteristics of modern transmitting equipment, lack of knowledge about corrective steps, and the "me first" approach too common today. This article is devoted to the second factor, corrective steps, with some discussion of the reasons why they are necessary.

One of the characteristics of many modern commercially built exciters, transceivers, and linear amplifiers is that they lack dial scales. Some may have a mark at 9, 12, and 3 o'clock, or even at every hour position, but many are blank. As a result, it's almost impossible to preset operating controls with any degree of accuracy. The only way to obtain proper performance is to tune up with reference to meter readings. Since amateurs want full output, it's no wonder that on-the-air tuneup has become so common.

The solution to this problem is simple — install useful dials. Here, useful means a dial that can be read to about one degree of arc or so. It certainly means one that's large enough to get your fingers on, is easy to read, and has no backlash. For many controls it also means a vernier knob.

Most users of commercially built equipment have put up with the lack of useful dials from fear of spoiling equipment resale value. This shouldn't be a worry, because it isn't necessary to change appearance, drill holes, or take other steps that will reduce resale value. Also no great amount of work is necessary. On most transmitters or amplifiers only three controls are involved: typically drive, tune and load. A couple of hours of work should take care of most cases.

The simplest approach is to remove the old knobs and replace them with dials having calibration marks close enough to be useful, typically 0-100 over an arc of 180 degrees. Many styles are available in junk boxes, surplus outlets, and stores. However, it's difficult to find small dials with the necessary calibrations. If you're fortunate enough to obtain such dials, put the removed knobs in a cloth bag and tie it inside the equipment where it won't get lost. This saves no end of trouble when it's time to sell or trade.

Another simple approach is to install a calibrated dial plate under the control mounting nut. These plates were

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common for many years but are scarce now. They can be made using dry-transfer kits similar to those for lettering, or the center portion of a piece of polar graph paper, suitably lettered, can be used to give calibrations each 2 degrees. Dial plates can also be hand drawn. Best appearance is obtained by making the drawing several times full scale then reducing it photographically.

Both these methods have one disadvantage: they don't have vernier action. Small vernier dials are usually available from Radio Shack, Olson or Lafayette in 1½, 2, and 3 inch (3.8, 5.1, and 7.6cm) sizes. These dials can be mounted on a false panel section using countersunk

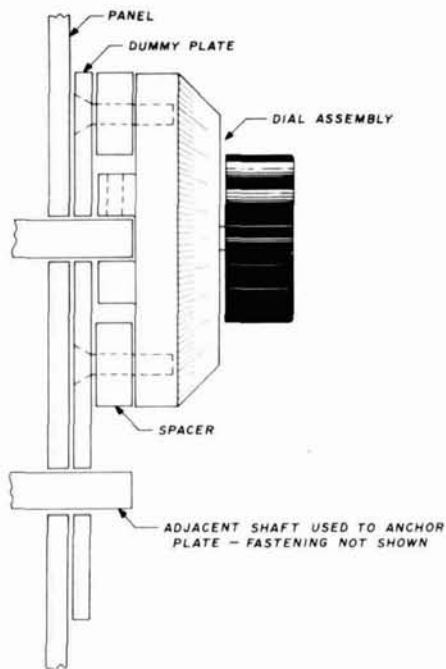


fig. 1. No-holes dial mount using a dummy plate.

screws. The assembly can be held in place by the control nut or by an adjacent nut as shown in fig. 1; by bending around the edge of the panel; or by a drilled hole hidden by the original knob. QST's "Hints and Kinks" contain other mounting ideas.

Another method, which involves considerable work but which offers the opportunity to obtain a "custom station," is to make a complete dummy front panel. Custom features such as combinations of equipment, special lettering, engraved calls, and so on can be had by this method. It's a good method for organizing the clutter of auxiliary controls that most stations accumulate. Whatever the method used, an additional item needed is a setting log or card giving the proper setting of each control for each preferred frequency or for band segments on the low frequencies and bands on the high frequencies. Plastic envelopes are convenient for these logs.

antenna tuner

The ability to return to a known dial setting is a big

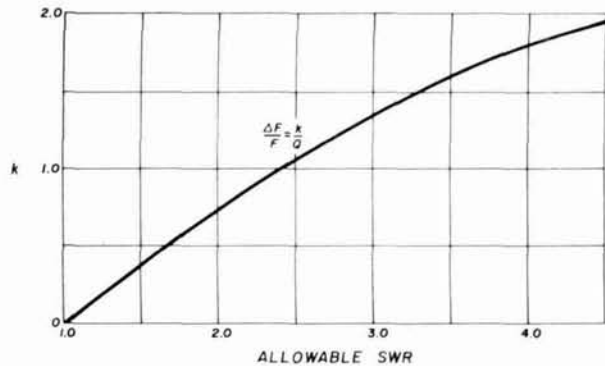


fig. 2. Bandwidth corrections for allowable swr.

help but doesn't fully compensate for another characteristic of modern transmitters and amplifiers, the fact that they're designed to work into a 50-ohm load with an swr no greater than 2:1. An easy way to see how restrictive this can be is to consider the effect of antenna Q. The Q will be around 70 for a typical close-spaced Yagi on 7 MHz. The response will be nominally within 3 dB for a change of ±50 kHz. However, the Q response curve must be multiplied by a factor, k, which takes into account the allowable swr. The way this factor varies with swr is shown in fig. 2. The maximum range of transmitter adjustment is used up with a frequency change of only ±37 kHz. Even with low-Q antennas such as a wide-spaced Yagi with a Q of around 7, where the transmitter adjustment range covers 350 kHz or so, there will be measurable difference in transmitter performance with a frequency shift of 30 kHz. No wonder on-the-air tuneup has become so common!

If we look at the reason for this, we find that the

Dummy antenna load fashioned from a paint can. Ten 510-ohm 2-watt resistors in parallel, immersed in mineral oil, dissipate 470 watts for 5 seconds — adequate for tune up.



culprit is the reactance caused by operating away from resonance. For example, the resistance and reactance values for a typical dipole are shown in table 1. For a one-per cent change in frequency, (70 kHz at 7 MHz), the radiation resistance changes by about 6 ohms, or less than ten per cent. The reactance change is over six times as large numerically.

The solution to the problem introduced by this reactance change is simple — use an antenna tuner. Furthermore, since antenna reactance causes most of the swr change, we can use a single variable element. The other antenna tuner elements can be fixed. The improvement possible by this reactance control method is evident from fig. 3. The upper curve is the swr expected with a typical wire dipole fed with a 50-ohm line. The swr reaches 2:1 for a one-per cent change in frequency. By simply cancelling the reactance, the swr seen by the transmitter changes to the lower curve. Its minimum swr is now lower, reaching 1.0; and 2:1 is reached only after a 5½ per cent frequency change. Note that the minimum swr occurs at a different frequency as far as the transmitter is concerned. Note also that the swr on the line does not change: it reaches about 7:1, causing increased voltage across the line, which may cause breakdown with small line and high power. The high swr also causes a small increase in line loss, usually entirely negligible. The

table 1. Impedance of a typical dipole antenna.

per cent resonant length	resistance (ohms)	reactance (ohms)
46	47	-95
47	53	-76
48	59	-38
49	65	0
50	71	+38
51	77	+76
52	83	+95

gain in frequency flexibility is far more important than these small problems.

The easiest way I've found to attain this single control action is shown in fig. 4. The pi network is conventional, with the arms continuously adjustable. The difference is in its use. L, C1 and C2 are preset to the band used and only C1 varied as frequency is shifted within the band. The indication for proper adjustment is a zero reading on the reflected power meter, which is an *ARRL Handbook* meter with only the reflected power elements connected. C1 is first preset to the table value, then adjusted as required when transmission begins. For a matched load, proper adjustment occurs with the reactance of each arm equal to the line impedance. This also gives the element values for a switched arm network.

dummy load

Good dials and a single-control matching unit are a big help in solving the tune-up problem, but it's still comforting to know that everything is tuned up on the nose. We can have this capability without radiating by adding another element — a dummy antenna automatically inserted into the transmitter output when the

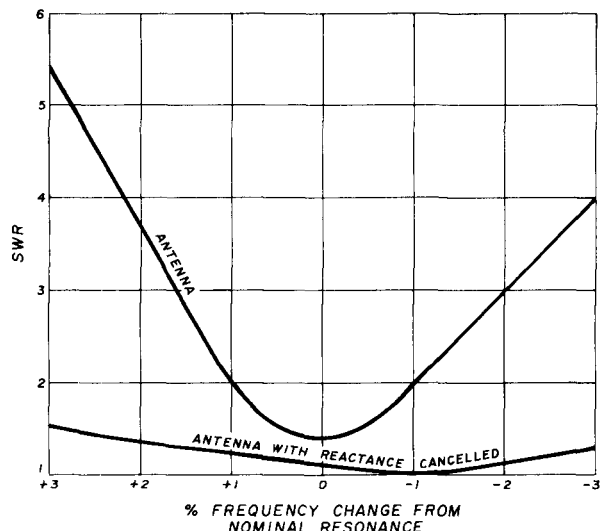


fig. 3. Typical swr for dipole antenna with and without corrective steps.

transmitter *tune* control is activated. A circuit for this is shown in fig. 5. The diodes prevent interaction between the external relay and the internal circuits. The switch allows the test signal to be radiated, primarily to determine initial matching network settings.

The dummy antenna can be a commercial or kit unit, but the large units rated at 1 kW are not needed in this service provided that tuneup is held to the few seconds needed to touch up preset controls. A dummy antenna isn't hard to build; the basic components are a handful of resistors. The following discussion is based on use of Allen-Bradley resistors. Units of other manufacture may be satisfactory, but the rating values should be secured from the manufacturer.

A 2-watt A-B resistor of the twenty-per cent series is rated for a continuous load of 2 watts for 100,000 hours when the resistor is mounted with 1-inch (2.5cm) leads and has a body temperature of 212°F (100°C); this occurs when the ambient is 122°F (50°C). The life rating increases by a factor of ten for a 122°F (50°C) reduction in body temperature. The allowable load increases by 40 per cent for a 10:1 reduction in life. For short-term loads the resistors, for the same mounting, ambient and life, are rated at 44 watt-seconds; i.e., 44 watts for one second.

Suppose one of these resistors is used as a dummy antenna for a five-second tune-up checks. Over a ten-year period, if used ten times a day, the load would be applied for about 50 hours total. Since the required life

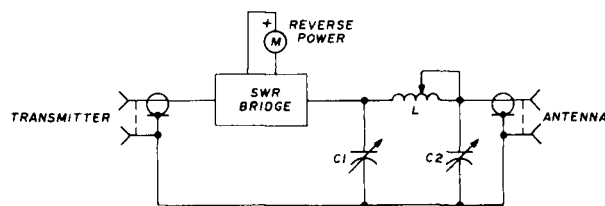


fig. 4. Antenna tuner for reactance compensation.

under load is so short, the load can be increased accordingly. Also, the resistor body temperature can be decreased by mounting the resistor on heavy fins that touch the ends of the body and by immersing the fins and resistors in cooling oil. The body temperature will then be essentially ambient, certainly no greater than 122°F (50°C).

As a result of these steps, the power input can be increased by 1.4 times for the reduction in temperature, and 1.4⁴ times for the acceptable reduction in life, or by 5.35 times. The rating is now 10.6 watts continuous, or 47 watts for five seconds. Ten 510-ohm resistors in parallel will dissipate 470 watts for five seconds; easily full output for a 600-watt-input transmitter of the type that runs at full output on tune, and ample for a 1 kW unit that tunes at 50 per cent of full output. Forty resistors will handle a maximum legal input transmitter.

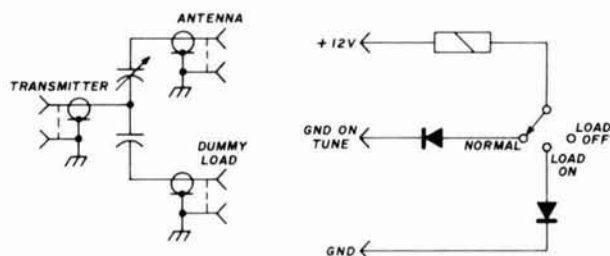


fig. 5. Circuit for dummy-load control during tune up.

A dummy load designed in this fashion is shown in the photo. The container is a one-quart paint can. Fins are copper. The 2-watt resistors are separated by three body diameters in each direction, and are staggered for good oil circulation. The cooling oil is light mineral oil, but transformer oil or hydraulic fluid are usable; mineral oil is odor and stain free. The unit shown is eight years old and has been used for tests up to 30-seconds duration with a 500-watt-input transmitter, repeated until the can became quite warm. Actually the rating method above seems to be quite conservative, since the change in resistance in this period has been much less than the 10-20 per cent expected.

the operator

With these three aids in place it's now possible to get on the air, correctly tuned up, without causing the slightest interference. The steps are:

1. Set the exciter, final amplifier and tuning dials to the logged settings for the band.
2. Activate the tune control, placing the transmitter on the dummy antenna, and touch up the tuning if readings aren't normal.
3. Start transmitting, observing the antenna tuner reflected-power meter; adjust the antenna tuner if needed.

These steps will result in the maximum possible signal and will also make life more pleasant for others on the channel.

ham radio

WHY WASTE WATTS?



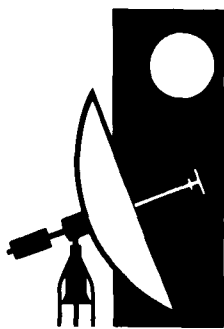
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vhf/uhf techniques

Joe Reisert, W1JAA

what's wrong with amateur vhf/uhf receivers — and what you can do to improve them

How many times have you heard the expression, "If you can't hear them, you can't work them?" Well, this old saw pretty well sums up one of the biggest problems faced by amateur vhf and uhf operators. The culprit usually turns out to be the receiver or converter.

A complete treatment of the subject of vhf and uhf converters would require a lengthy article which is beyond the scope of this column. Therefore, I will limit my remarks to a general nature and, wherever possible, use references for more detailed information. Furthermore, I will only direct my remarks toward vhf/uhf converters; I'll leave the i-f or tunable receiver up to the user. Hopefully the remarks in this column will stimulate some interest in upgrading your converters, and will make your vhf/uhf operating more enjoyable.

general converter problems

The primary problems with most vhf/uhf converters are high noise figure, spurious responses, gain compression and "intermods" or IMD (intermodulation distortion), poor stability, and burnout. I'll briefly describe each of these problems, suggest some cures, and finally, recommend some tests to measure converter performance.

High noise figure is a symptom of almost every vhf or uhf converter I have ever measured. Principal causes (disregarding defective components for the moment) are high noise figure in the preamplifier, low preamplifier gain, high conversion loss in the mixer, and high i-f noise figure. Combinations of the above problems are also prevalent — the overall effect is poor sensitivity.

Spurious responses are also quite common in vhf and uhf converters. Unfortunately, instead of eliminating the spurious problem, most operators learn to live with it. Typical causes are insufficient filtering in the rf and local oscillator circuits, poor choice of intermediate frequency, and instabilities in either the preamplifier, oscillator, or frequency-multiplier stages. The overall result is the appearance of undesired signals in the frequency range of interest.

Intermodulation distortion and gain compression are usually caused by insufficient dynamic range at some point in the converter or i-f. The most likely culprits are poor linearity or excessive rf gain, or both. The requirements for low noise figure enhance the problem since rf gain and lower device operating currents are necessary. The usual result is the appearance of undesired signals which cannot be eliminated unless attenuation is placed ahead of the converter.

Poor stability, like spurious responses, is a problem many vhf/uhf operators learn to live with. It almost goes without saying that the i-f following the converter must be stable. The usual causes of instability are the oscillator circuit (and its components), the power supply, and the physical surroundings of the oscillator. Poor stability will cause the received signal to drift or rapidly change frequency.

Burnout is a perennial problem which has increased with the widespread use of solid-state devices. It can be caused by electrical discharge (such as lightning), high rf signal levels, or improper power supplies — anything that overstresses the devices used in the converter. The typical result is a dead converter without any prior warning.

Before discussing any specific circuit recommendations, I would like to give my usual pitch for the *modular* approach to vhf/uhf converter design where virtually every stage or function in the converter occupies a separate chassis or enclosure. There are many advantages to this system. First of all, modular converters are easy to work on because you can work on one circuit at a time — none of the other circuits is affected. Why build a new local oscillator chain every time you build a new converter or preamplifier? Furthermore, optimum performance of each module can be attained on your bench before you test the circuit in your converter. Shielding between stages is virtually assured with separate modules so crosstalk is vastly improved. Finally, if any module fails, it can usually be rapidly bypassed so operation will not be completely curtailed or severely degraded.

The primary disadvantages to the modular approach to vhf/uhf converter design are size, complexity and cost. However, if optimum performance is your goal, the advantages far outweigh these shortcomings. Just think how easy it will be to try out a new preamplifier or mixer if you use the modular system. All it takes is a simple substitution of modules, a one- to two-minute operation. If the change is not productive, the converter can be restored to its original configuration in seconds. You no longer have to build a complete new converter just to evaluate a new circuit.

A block diagram of a typical vhf/uhf converter is shown in fig. 1. If you use the modular approach, up to ten individual module units could be used, but usually some units such as the crystal oscillator and frequency multipliers can be combined in one module.

recommendations

The overall noise figure of a well designed vhf con-

verter is usually determined by the preamplifier. The gain of the preamplifier should typically be 10 to 12 dB, minimum, but not greater than 18 to 20 dB. Most vhf/uhf preamplifiers with more than 18 to 20 dB gain are only conditionally stable (many oscillate if terminated in an impedance other than the design value — usually 50 ohms). As a rule of thumb, for high dynamic range the stage gain should be about 6 dB greater than the noise figure of the system following that stage. For low-noise converters stage gain should be 10 dB greater than the noise figure of the following system.

If the mixer has a 5 dB noise figure, for example, 15 dB of preamplifier gain would be desirable for minimum noise figure; 11 dB gain would be sufficient for a high

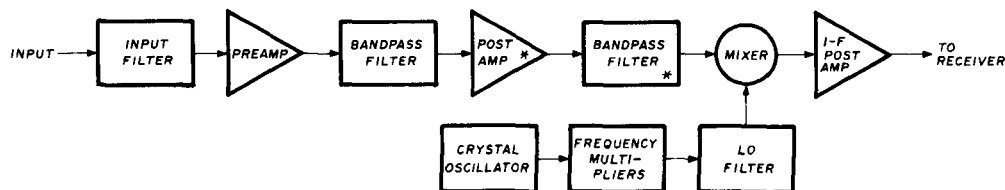


fig. 1. Block diagram of a typical vhf or uhf converter. The blocks marked with an asterisk are not necessary if high dynamic range and moderate noise figure are desired. The frequency multiplier is needed only in those cases where local-oscillator injection is above about 125 MHz (the upper limit for recommended overtone crystals).

dynamic range converter. Notes on calculating gain and noise figure are contained in the appendix of reference 1. Reference 1 also discusses the benefits of low noise preamplifiers and illustrates recommended circuits and devices.

Although it has been stated many times in the past, it should be reiterated that maximum gain and lowest noise figure are rarely coincidental in preamplifiers. In addition, the input filter to a converter should be a low-loss, single resonator type such as a quarter-wavelength coaxial cavity¹ because any loss ahead of the converter will be added directly to its overall noise figure. Multiple-resonator input filters should be avoided because the input mismatch to a typical low noise figure preamplifier may cause the input tuning to change, thereby increasing the noise figure.

Quarter-wavelength input filters should be tuned for minimum vswr into a well matched 50-ohm load. Then they should be connected to the preamplifier with a *short connection* (such as a coaxial adapter) and *never be retuned*. Retuning a filter after it has been connected to a preamplifier frequently results in increased insertion loss unless precision noise figure measurements are used.

Other sources of high noise figure are high mixer conversion loss and poor i-f noise figure. A suitable low loss mixer will be discussed later in this column. The typical i-f used by most vhf/uhf operators is a commercial 28- to 30-MHz communications receiver. It is not unusual to find that the noise figure of such a receiver is as high as 10 or 20 dB! Therefore, it is recommended that a low noise figure preamplifier be placed ahead of the receiver. This will also reduce the need for high preamplifier gain, thereby increasing dynamic range. A suitable i-f preamplifier is discussed in reference 2.

As pointed out earlier, spurious responses are quite common in vhf/uhf converters. Careful choice of the i-f is a very important determining factor in this regard. Generally speaking, 28-30 MHz is an optimum choice. Lower intermediate frequencies are more susceptible to i-f breakthrough and increase the complexity of filtering out the image frequency. Reference 3 provides some good guidelines for choosing an i-f. Image rejection of at least 30 dB should be a minimum goal.

Filtering of the rf and local oscillator circuits should be carefully considered since insufficient filtering will enhance spurious responses. Proper filtering of the local oscillator is seldom given adequate attention in most amateur converters, and subjects the mixer to additional

undesired frequencies. The result is similar to the computer programmers' expression, "GI-GO" (garbage in — garbage out).

Interstage and local-oscillator filters should preferably have multiple resonators (tuned circuits) to enhance selectivity. Losses of 1 to 2 dB are usually tolerable since there is generally adequate gain available to compensate for filter losses. Interdigital filters⁴ are preferred for uhf while comb-line and helical resonator types^{5,6} are preferable for vhf.

A fundamental oscillator frequency of 90 to 125 MHz is recommended for all converters for 144 MHz and above. Lower frequency oscillators generally cause more spurious frequencies, are more difficult to adequately filter, and can cause unwanted reception of television and fm broadcast signals. A suitable oscillator circuit is shown in fig. 2 and will be discussed later in this article.

Frequency doublers are preferred for multipliers since they are more efficient (especially the push-push type), more stable, and easier to filter. Frequency triplers, however, are acceptable when the output is below 300 MHz. Typical doubler circuits are shown in fig. 3.

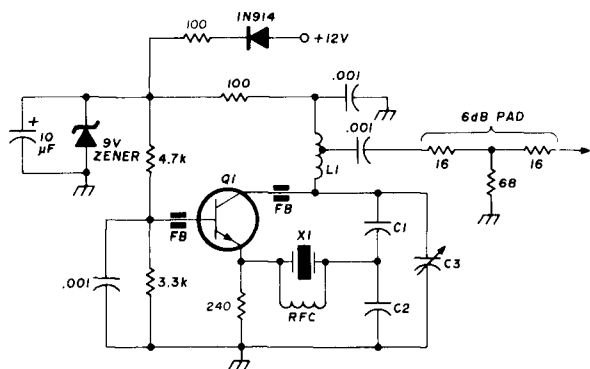
Another cause of spurious outputs in vhf/uhf converters is instability in preamplifiers and local-oscillator/multiplier stages. Care should be taken to adequately decouple and shield all circuits in the local-oscillator chain to prevent this type of instability. The modular approach is a definite benefit in this regard.

intermodulation distortion

Gain compression and intermodulation distortion are particularly prevalent in most of the vhf/uhf converters I've seen. Gain compression is simply the lack of dynamic range with a signal at the input. Intermodula-

tion distortion, which must not be confused with spurious responses, is the result of mixing the harmonics of one or both of the two input signals which in turn generate other frequencies within the desired passband. This is caused by non-linearities, either in or ahead of the mixer, and has been well documented.^{7,8}

First of all, you must insure that only the desired signals enter the converter. This can usually be accomplished with narrowband filters at the converter input and throughout the rf paths as discussed previously. If



- C1 10 pF mica
- C2 20 to 60 pF mica. Use as high value as possible (until circuit just oscillates reliably when C3 is tuned through resonance)
- C3 20 pF piston or miniature trimmer
- L1 8 turns no. 24 (0.5mm) on Amidon T37-12 toroid core, tapped 3 turns from cold end
- Q1 Fairchild 2N5179 recommended but 2N2857, 2N3563, 2N918 or equivalent may be substituted
- RFC 0.39 µH. Resonates with crystal holder capacitance (4 to 6 pF typical) for parallel resonance at crystal frequency
- Y1 90 to 125 MHz, 5th or 7th overtone, series-resonant, HC-18/U crystal. Cut leads as short as possible (1/4" or 6mm maximum)

fig. 2. Recommended 90 to 125 MHz crystal oscillator circuit for vhf/uhf converters. Output is 5 to 15 mW. Crystal should be a high-quality 5th or 7th overtone type. The ferrite bead (FB) prevents undesired oscillations above 500 MHz.

the undesired signals are too strong or too close to the input frequency, additional precautions must be taken.

The mixer is usually the major source of IMD difficulty since it is essentially a non-linear device and sees all input signals that remain after filtering and preamplification. The best solution to mixer-generated intermod is to use a mixer which has good dynamic range. Bipolar transistors are extremely poor in this regard and should be avoided at all cost. Fets, including the dual-gate mosfet types, are good at vhf but are poor performers above 300 MHz.

The double-balanced mixer is recommended since it generates fewer spurious responses than single-ended or single-balanced designs. The fet double-balanced mixer is recommended for operation below 300 MHz because it has good dynamic range and conversion gain.⁹ For all around versatility, however, the Schottky-diode double-balanced mixer is hard to beat since inexpensive units (less than \$7.00 in single quantities) cover the frequency

range from 5 to 500 MHz and present 50 ohms at all ports. The circuit of one popular type is shown in fig. 4.

For best intermodulation performance the Schottky double-balanced mixer should have sufficient local-oscillator injection (10 to 20 milliwatts) and all ports should be properly terminated. The recommended procedure is to use a 3 to 6 dB resistive attenuator on the local-oscillator port (with a commensurate increase in local oscillator power), and a well matched i-f preamplifier on the i-f port, preferably with a diplexer. This subject is thoroughly discussed in reference 9. An extension of this technique would be to use one of the high dynamic range double-balanced mixers. They require even higher local oscillator power but the higher mixer outputs may cause the i-f to generate intermodulation products so their use may not necessarily justify the added expense.

The gain problem is a whole, separate subject. I have noticed all too often that far too many preamplifier stages are used ahead of the mixer. Generally speaking, two stages, (one preamplifier and one postamplifier) should be more than sufficient, even for the lowest noise receiver. Gains ahead of the mixer totalling 30 dB or more are definitely undesirable. High gain rarely contributes any worthwhile performance benefits and decreases the dynamic range of the receiver.

The linearity of the postamplifier (the amplifier stage after the mixer) is also very important. As a general rule of thumb, this stage should operate with a collector (or drain) current of four to five times the corresponding current of the preamplifier. This is necessary because the signals present in this stage are typically 10 to 15 dB higher (gain of the preamplifier less loss of the filter) than at the receiver input so the postamplifier is more susceptible to non-linearities. It may be worthwhile to note that for each dB of extra gain ahead of the mixer the intermodulation distortion increases by 3 dB! If lowering the gain ahead of the mixer causes i-f problems (poor noise figure, etc.), a postamplifier can be added after the mixer.

stability

Frequency stability can sometimes be a problem. The principal causes of drift are the actual oscillator circuit, its components, and, in particular, the crystal. Only high quality components and overtone crystals should be used. Inexpensive crystals should not be used. Inexpensive crystals frequently generate spurious outputs, noise, and drift. Drive levels to the crystal should be kept to a minimum commensurate with reliable performance. Frequency-pulling components such as trimmer capacitors should be avoided at all costs as they will seriously degrade the stability and spurious performance of even a good high-Q crystal. The crystal should be allowed to operate at its natural series-resonant frequency, and the oscillator power supply should be regulated. A recommended circuit is shown in fig. 2.

Needless to say, heat-generating devices such as vacuum tubes should not be located near an oscillator because they will seriously affect stability. Furthermore, all oscillator components should be rigidly mounted to prevent any mechanical instabilities.

Burnout has increased with the use of higher power transmitters and solid-state converters. All circuits, as a minimum, should use an *idiot* diode (a diode in series with the power supply as in figs. 2 and 3). They prevent damage due to polarity reversals and lower crosstalk. Regulated power supplies for solid-state equipment are highly recommended and inexpensive due to the ready availability of three-terminal voltage regulators.¹¹ A power supply which is used for relays should never be used to power a solid-state circuit because relay coils induce large voltage spikes on the power supply line during switching operations. It shouldn't be necessary to mention it, but never operate a circuit at voltages (or power dissipation) above the manufacturer's maximum specifications.

Other forms of burnout are excessive rf input or transients. The ordinary coaxial relays that are used by vhf/uhf amateurs often have only 30 to 40 dB isolation between the transmit and receive ports. If you're running a high power transmitter (500-600 watts output) this means that up to 0.5 watt of rf power can be impressed across the receiver input.

One simple cure to this problem is to use an additional lower power relay in series with the receiver for additional isolation. Another solution is to use a limiter ahead of the preamplifier. Even a single silicon or hot-carrier diode across the base-to-emitter junction of a bipolar transistor will help (see fig. 5). Germanium or back-to-back diodes across the input line should be avoided since they frequently turn on too early and can also generate spurious responses from out-of-band signals.

Out of band transients and excessive rf can usually be eliminated with a good input filter as discussed previously. It is not uncommon to see *volts* of rf energy on the transmission line from a vhf/uhf antenna which is near a high-frequency transmitter such as a 10-80 meter amateur station.

Lightning is also a real problem. If two relays are used (as described above), they can be connected so the pre-

amplifier input is terminated in a 50-ohm dummy load when the receiver is not in use (see fig. 6). A short-circuit or open return may cause a preamplifier to oscillate. This oscillation could also cause damage to the device and may generate local, self-caused interference.

Another possibility for lightning protection is a high-pass filter which is designed with a cutoff frequency which is 10% to 50% below the band of interest (see fig. 7). Since most of the energy in a lightning strike is concentrated below 50 MHz a highpass filter will provide a measure of protection against nearby electrical storms.

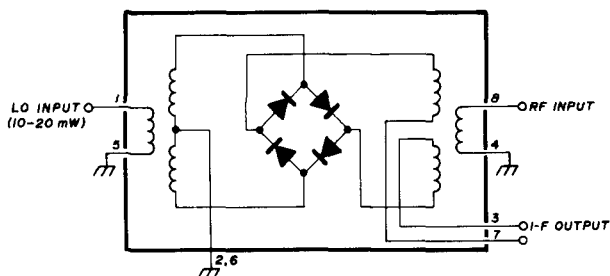
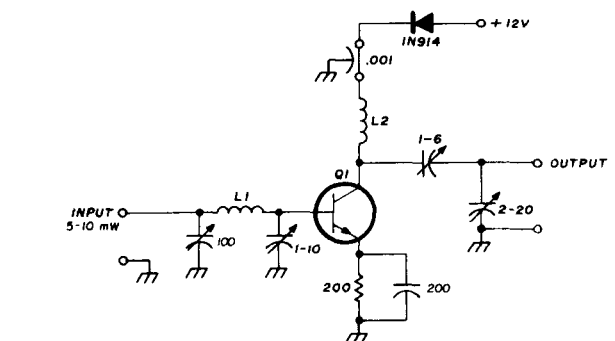


fig. 4. The Anzac MD108 double-balanced mixer is useful over the frequency range from 5 to 500 MHz and is recommended for amateur vhf/uhf converters. This device is priced at \$7.00 in small quantities (plus postage) and is available direct from the manufacturer, Anzac Electronics, 39 Green Street, Waltham, Massachusetts 92154.

However, there is virtually no protection against a direct hit!

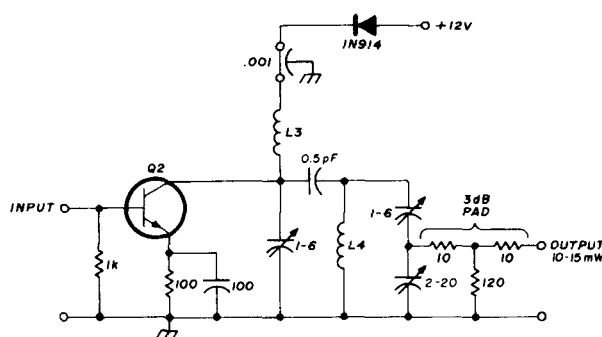
testing and evaluation

There's no question that noise figure measurement is the most important test of converter performance and must be performed if proper operation is desired. As pointed out in reference 1, the measured noise figure may be optimistically low if a 5722 noise diode is used. The gas-discharge tube or hot-cold test are recommended above 400 MHz. The silicon diode noise generator is recommended only for optimizing the noise perform-



A 100-200 MHz

- L1 12 turns no. 28 (0.3mm) on Amidon T25-12 toroid core
- L2 7 turns no. 24 (0.5mm), air core, closewound on 0.1" (2.5mm) diameter



B 200-400 MHz

- L3,L4 2 turns no. 22 (0.6mm), air core, 1/8" (3mm) diameter, 1/4" (6.5mm) long
- Q1,Q2 Fairchild 2N5179 recommended but 2N2857, 2N918, FMT2060 or equivalent may be substituted

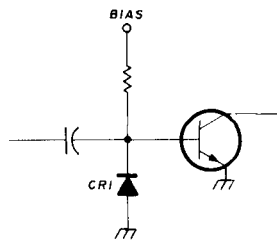
fig. 3. Two frequency doubler circuits which are recommended for use with vhf/uhf converters. The circuit in (A) is suggested for inputs in the range from 90 to 120 MHz. The doubler in (B) is recommended for inputs in the range from 180 to 220 MHz. The 1N914 diode in series with the power supply lead is the "idiot" diode discussed in the text.

ance of a converter — it can't be used for quantitative measurements.

The primary things to look for when evaluating converter noise figure are poor image rejection and nonlinearities in the i-f and detector. One good test is to compare your converter or preamplifier with another one (preferably one with a known noise figure) and note the difference. You can get a good idea of how well your converter measures up and absolute numbers are not necessary. For more information on the subject of noise figure, references 12 and 13 are recommended as starting points.

It's not easy to test for spurious responses but the simplest test is to substitute and/or bypass modules in

fig. 5. Simple limiter circuit is helpful in reducing burnout problems in preamplifier input stages. Diode CR1 is a low capacitance (1.0 pF maximum) silicon or hot-carrier diode such as the Hewlett-Packard 5082-2810.



tion of the undesired signal is usually necessary before corrective action can be taken. If you are fortunate enough to have access to a spectrum analyzer, spurious troubles can be quickly pinpointed.

If you use the modular approach, gain compression and intermod performance are easily checked without expensive test equipment. All you need is a coaxial type attenuator in the 10 to 15 dB range. If this is not available, 100 feet (30m) of RG-58/U coaxial cable is acceptable (at 432 MHz this represents approximately 12 dB attenuation).

The test procedure is to connect the attenuator between various stages of the receiver to see where the problem is being generated. If the attenuator is placed after the preamplifier and the problem persists, the preamplifier is probably the source of the difficulty. If the problem goes away, however, it's probably being generated further down the chain and a similar test of the mixer is required.

Once you have pinpointed the problem it can be dealt with accordingly. It may even be desirable to have a built-in system for switching in additional attenuation ahead of the mixer if the offending signal is not always present (such as a local television transmitter, etc).

Converter stability can best be tested by using a stable crystal calibrator with known stability. A variable voltage supply on various converter circuits can provide

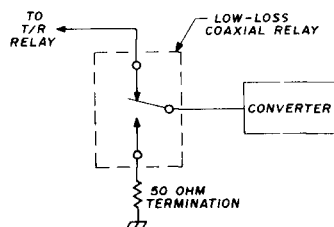
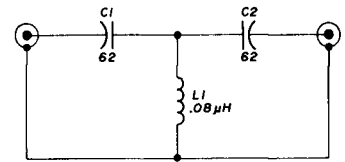


fig. 6. Simple relay protection circuit which enhances transmit-receive relay isolation.

fig. 7. Simple 50-MHz high-pass filter to decrease the effects of lightning and high-frequency interference. Keep all leads as short as possible to prevent circuit losses.



C1, C2 62 pF miniature capacitor

L1 0.08 μ H, 4 turns no. 20 (0.8mm), air core, 1/4" (6.5mm) diameter, turns spaced one wire diameter

clues to the source of stability problems. A heat gun or hair dryer can be used to check for thermal instabilities.

Burnout is very difficult to evaluate since most burnout tests are, by nature, catastrophic. Suffice to say that if you have followed all of the previous recommendations, you have done about all you can do.

final remarks

The intent of this writeup is not to frighten you but to get you to try your hand at improving your own vhf or uhf converter. You will probably find that even if only one circuit is improved it will be worthwhile. Whenever you replace or modify a circuit you should *always* check the noise figure to make sure that the change resulted in an improvement — you may find that it was a move in the wrong direction!

I would like to once again reiterate that the use of quality components and the modular approach to vhf/uhf converter design will quickly pay for itself in terms of performance, versatility, and numbers of stations worked. It will also spur you on to trying new circuits and devices as they rapidly become available in today's highly volatile communications industry.

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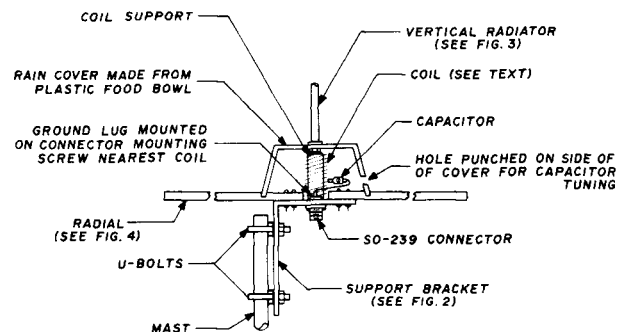
An easy-to-build antenna that provides a theoretical 3-dB gain over a quarter-wave groundplane

After operating two-meter fm mobile for some months I decided to operate from my home and built a vertical 5/8-wavelength antenna. Comparison with a 1/4-wavelength groundplane showed improved performance. I was able to work repeaters with the 5/8-wavelength vertical that I couldn't work with the groundplane. The antenna described here has been in operation since April, 1973. It's only 25 feet (7.6m) above ground. The lowest vswr obtained was 1.1 at 146 MHz, and the highest was 1.5 at 147 MHz. The antenna was made from junk-box parts and a discarded television antenna. Power levels of 100 to 150 watts can be handled safely. Greater power can be used by changing the series capacitor (fig. 1) to a variable capacitor with air dielectric, such as the APC type.

construction

Construction isn't critical and parts are easily obtained. The coil-support ceramic spacer and capacitor were obtained from a surplus military radio. The plastic weather cover was acquired from a local supermarket. You'll need an electric drill, drill bits as shown in the detail drawings, a 10-32 (M5) tap and holder, and a tapered reamer to make the 5/8-inch (16mm) diameter hole for the SO-239 connector. A bench vise is handy to bend the aluminum support bracket (fig. 2). The U-bolts were purchased from a local radio-TV parts dealer.

The assembled antenna is shown in fig. 1; details for making the support bracket, vertical radiator, and ground radials are given in figs. 2 through 4. Stainless steel hardware should be used if available. I used only three screw sizes to assemble the antenna: 4-40 (M3) for mounting the SO-239 connector, 6-32 (M 3/5) for mounting the radials, and 10-32 (M5) for the coil-support section. The 10-32 (M5) threaded stud at the top of the coil support was made from a 1½ inch (38mm) long screw with the head removed. A lug, lock



quantity	description
1	support bracket (reference fig. 2)
4	radials (reference fig. 4)
1	vertical radiator (reference fig. 3)
1	plastic cover (see text)
2	mast U-bolts (see text)
1	coaxial SO-239 connector
1	coil support — ceramic steatite pillar, Birnbach no. 445G or equivalent size 2½" (63.5mm) high by 3/4" (19mm) diameter threaded 10-32 holes both ends
1	capacitor — 7-45 pF ceramic trimmer, Erie type no. 503-000D7-45 or equivalent. Do not use mica compression type

Note A. Top of radiator can also be sealed by squeezing in vise, using a plastic cap of appropriate size, or filling the end with 2" (51mm) of caulking compound.

fig. 1. Assembled 5/8-wavelength vertical antenna for two meters.

washer, and nut are installed at the top of the support bracket and another lug on the screw nearest the coil support holding the SO-239 connector.

After assembling the parts described above, wind a coil of 9 turns using number 10 or 12 AWG (2.6 or 2.1mm) solid enamelled copper wire around the coil support. Space the turns to occupy the length of the support (2½ inches or 63.5mm). Solder the coil ends to the

By Ed Spadoni, W1RHN, 91 Tower Street, Dedham, Massachusetts 02026

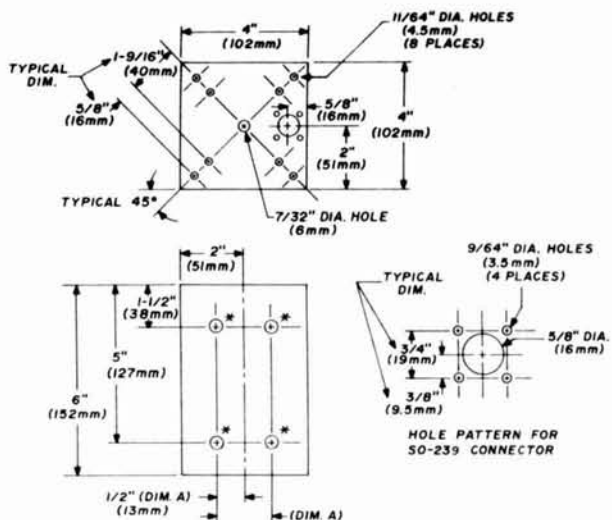
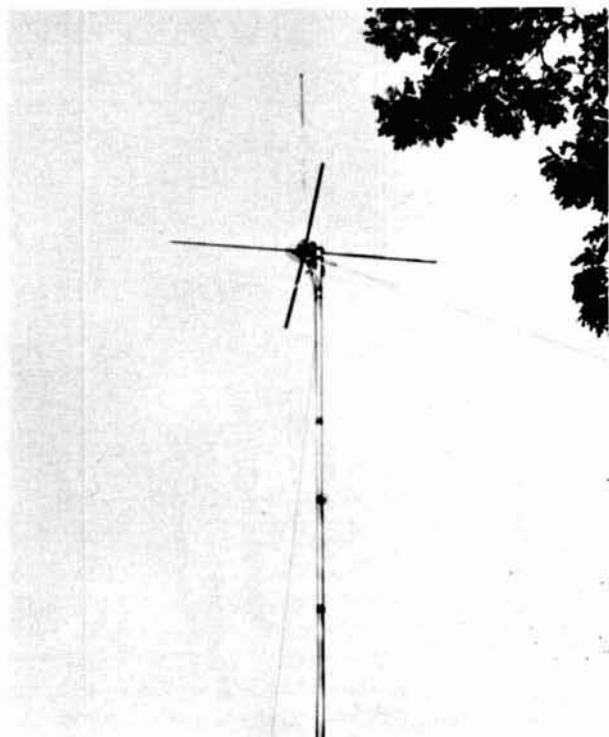


fig. 2. Support bracket details. Dimension A and holes marked with an asterisk are sized to fit available U-bolts. Material is 1/8" (3mm) aluminum.

lugs (see fig. 1). Next, solder the capacitor to the coil, two turns up from the ground end of the coil. Attach the other end of the capacitor to the center connector of the SO-239 connector. Install the capacitor so that the adjustment screw is accessible from the side of the cover.

To install the plastic rain cover, drill a 7/32-inch (6mm) diameter clearance hole on top for the stud to project through the cover. Slip the cover over the stud, and a flat metal washer and a lockwasher, then screw on

Installation of the two-meter vertical at W1RHN.



the vertical radiator until it's tight. A capacitor-adjustment hole is made through the side of the plastic cover by aligning a scriber or centerpunch opposite the capacitor adjusting screw and penetrating the plastic cover. The hole should be about 1/4 inch (6.5mm) diameter.

tuning

I used my ICOM IC-20 and a Bird vhf directional wattmeter to adjust the antenna for lowest vswr. With

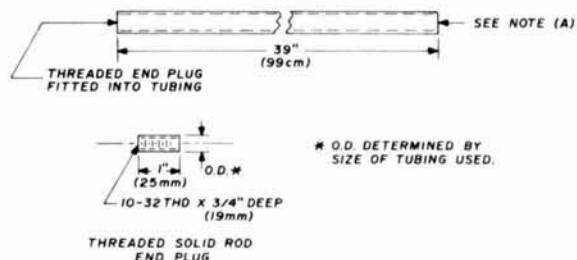


fig. 3. Construction details for the vertical radiator. Material is aluminum tubing, 7/16" (11mm) or 1/2" (13mm) OD, 1/16" (1.5mm) thick wall. Solid aluminum rod, if available, will provide sturdier construction and will avoid need for making end plugs to seal top. The end plug fits flush with the end of tubing and is held in place by "dimpling" with a center punch.

power applied to the antenna, I adjusted the capacitor with a nonmetallic alignment tool for the lowest reflected power on the wattmeter, using a test frequency of 146.52 MHz. If you don't have a vhf swr bridge or directional wattmeter, a field-strength meter can be used as an indicator. When using this method, adjust the capacitor for maximum output.

final comments

As with all vertical antennas, this 5/8-wavelength antenna is omnidirectional. However, it has approximately

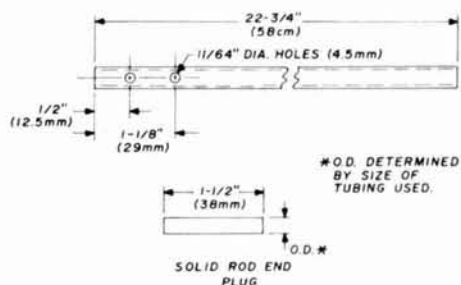


fig. 4. Radial element construction details. Install end plug flush with tubing, then drill 11/64" (4.5mm) holes ("dimple" plug in place before drilling).

3 dB gain over a 1/4-wavelength groundplane and is an excellent antenna for all-around operation. With it I can consistently acquire repeaters 50 to 60 miles (80 to 96km) away. Under good conditions contacts 100 to 200 miles (160 to 320km) away have been made, both through repeaters and in the simplex mode.

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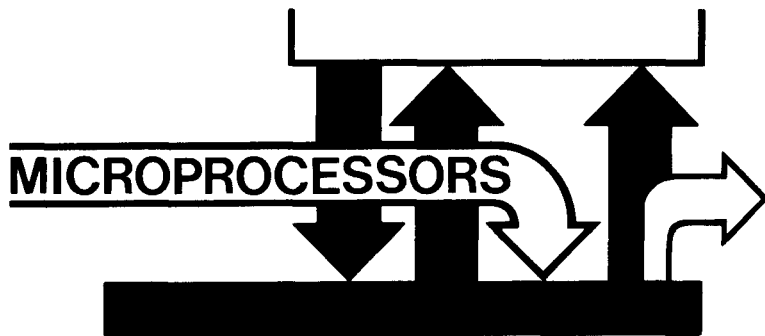
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8080 microcomputer output instructions

In the *microprocessor column* last month we discussed different types of simple input/output (I/O) devices and provided a listing of general principles of interfacing that apply to a wide variety of computers. This month, we would like to explain how software or computer instructions cause an I/O device to operate.

controlling power with a microcomputer

The I/O device that we shall choose for our discussion is the optically isolated solid-state ac relay. These relays can control any ac power device within the output current ratings of the relay. Shown in *fig. 1* are typical solid-state relays which are available at prices ranging from \$5 to \$20 in small quantities. These relays permit a single TTL output signal of logic 0 or logic 1 to control up to 10 amperes of 220 Vac power (the Hamlin model 7522 relay shown at the top center of the photograph). Internally each relay contains a light-emitting diode, a light-sensitive transistor, a power triac, and a transparent dielectric optical path that isolates the digital and power circuitry and can withstand a voltage difference of at least 1000 volts.

A typical microcomputer I/O circuit that employs the solid-state relay is shown in *fig. 2*. Recall from the preceding column that the microcomputer sends synchronization pulses, called *device select pulses*, to the I/O device. In *fig. 2* these are the pulses from the SN74154 decoder circuit. For an 8080 microcomputer each pulse from the decoder has a time duration of only 500 ns. It should be clear that a single 500 ns pulse cannot sustain the continuous operation of an ac power device. What is required is a simple interface between the microcomputer and the solid-state relay that will permit the ac power device to operate continuously, if it is so desired. A suitable interface is a single SN7474 positive-edge triggered flip-flop and a single buffer from a SN7407 hex buffer/driver chip. The buffer is needed since it is not good engineering practice to drive a solid-state ac relay directly from the output of a flip-flop.

With the aid of a suitable program, the microcomputer and SN74154 decoder can generate individual device select pulses that either clear or set the SN7474 flip-flop. To clear the flip-flop, and thus turn on the ac power device, only a *single* 500 ns pulse is needed. The flip-flop output, Q, will remain at logic 0 until a single 500 ns pulse is applied to the preset input, at which time the ac device will turn off.

It should be noted that any simple open collector gate or inverter can be used as the buffer between the output of the flip-flop and the input of the solid-state relay. Suitable choices would be the SN7401 or SN7403 2-input NAND gates, a SN7405 inverter, or a SN7409 2-input AND gate.

the output instruction

We shall discuss the subject of microcomputer instructions in considerable detail in subsequent columns. To summarize such discussions, there are 78 different instructions for the 8080 microprocessor chip, and a total of 256 variations of these instructions. Each instruction contains a single 8-bit *instruction code*, which indicates which type of operation or group of operations the microcomputer will execute. Some instructions contain two or three 8-bit bytes that are present in successive memory locations. A *byte* is defined as a group of eight contiguous bits occupying a single memory location.¹ Thus, 8080 microprocessor instructions are either 8, 16, or 24 bits long, with the first eight bits always being the instruction code.

The *out* instruction is a 16-bit instruction that consists of two successive 8-bit bytes located in successive memory locations. The first byte, in binary code, is always 11010011_2 . The second byte can be any 8-bit binary number from 00000000_2 to 11111111_2 (the subscript 2 denotes a binary code); this is the device code of

By Peter R. Rony, David G. Larsen, WB4HYJ, and Jonathan Titus

Mr. Larsen, Department of Chemistry, and Dr. Rony, Department of Chemical Engineering, are with the Virginia Polytechnic Institute and State University, Blacksburg, Virginia. Mr. Jonathan Titus is President of Tychon Inc., Blacksburg, Virginia.

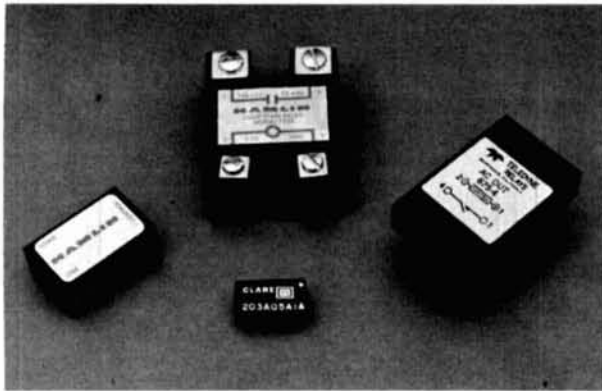
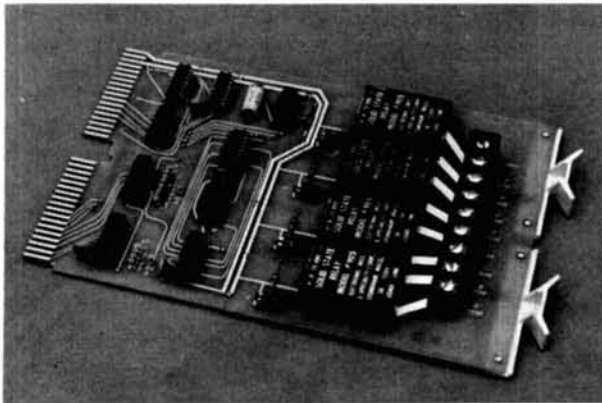


fig. 1. Typical optically isolated solid-state relays, including, from top left to top right, Hamlin 701-11-5 (1.5A, 120 Vac), Hamlin model 7522 (10 A, 220 Vac), Teledyne 657-4 (3 A, 120 Vac), and Clare 203A05A1A (750 mA, 120 Vac). The printed-circuit board shown at the bottom contains four Electronic Instruments and Specialty Corp. relays (3 A, 120 Vac) and all necessary external device addressing circuitry.



the specific output device that will receive eight bits of data from the accumulator. The instruction can be summarized as follows:

11010011₂ Generate a device-select pulse, with the aid of an 8-line-to-256-line decoder circuit, to allow an 8-bit data byte present in the accumulator to be sent to the desired output device. The contents of the accumulator remain unchanged.

simple program

The simplest program that incorporates the *out* instruction is probably the one given below:

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memory address	instruction byte	description
0	11010011	Send device-select pulse to device given by following 8-bit device code
1	00000000	Device code for clear input to SN7474 flip-flop
2	01110110	Halt the microcomputer

An 8080 microcomputer operating at a clock rate of 2 MHz will execute this program in 8.5 μ s. The ac power device will remain on once the program has been executed. To turn off the device, a slightly different program is required:

memory address	instruction byte	description
0	11010011	Send device-select pulse to device given by following 8-bit device code
1	00000001	Device code for preset input to SN7474 flip-flop
2	01110110	Halt the microcomputer

The ac power device will turn off after the second instruction byte in the program and remain off after the microcomputer halts. A more practical program requires additional instructions. Several such programs can be found in reference 1. Many of them have the following basic form:

memory address	instruction byte	description
.	.	
.	.	
.	.	
23	11010011	Turn solid state relay <i>on</i> , i.e., send device-select pulse to the device given by the following 8-bit device code
24	00000000	Device code for clear input to SN7474 flip-flop. When the flip-flop is cleared, the solid-state relay turns <i>on</i>

This section of the program may have various decision points that determine whether or not the solid-state relay is turned off. Typical decisions include

- Has sufficient time elapsed?
- Has the antenna reached its correct azimuth?
- Is the temperature of the final amplifier too high?
- Is the vswr too high?

.	.	
.	.	
.	.	
107	11010011	Turn solid state relay <i>off</i> , i.e., send device-select pulse to the device given by the following 8-bit device code
110	00000001	Device code for preset input to SN7474 flip-flop. When the flip-flop is set, the solid-state relay turns off.
.	.	
.	.	
.	.	

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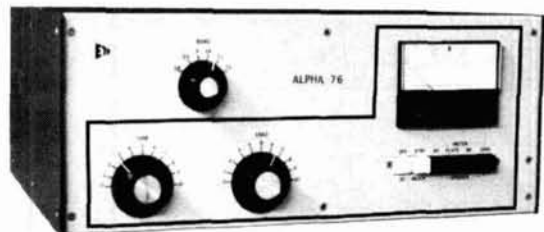


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Keep in mind that a memory address contains sixteen bits. When we write "memory address 0" we really mean the memory address corresponding to the following 16-bit binary word: 00000000 00000000. Note that we have split the sixteen bits into two parts, the most significant eight bits and the least significant eight bits. These are called the HI (or H) and LO (or L) memory addresses, respectively.

With the aid of the above program, the solid-state relay shown in fig. 2 will turn on and off according to various decisions made by the program. A typical micro-computer-controlled system could easily have several such relays.

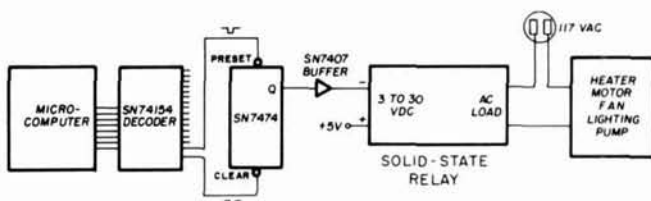


fig. 2. A typical I/O circuit for a power ac device such as a fan, heater, motor, or antenna control.

In a more orderly and systematic treatment of the 8080 microprocessor, you would probably introduce the 8080 instruction set prior to the discussion of any particular instruction, such as the *out* instruction described this month. Since we do not believe that you are willing to wait four months until we get to the *out* instruction, we have decided to treat it first. Next month we will provide a simple microcomputer program that generates device-select pulses to turn a device such as an antenna rotator or a fan on or off.

The authors will present a two-day seminar on micro-computers at the Virginia Polytechnic Institute and State University Extension Center in Reston, Virginia sponsored by Virginia Polytechnic Institute and State University Extension Division on March 12-13, 1976, and a five-day short course on digital electronics (with some discussion of microcomputer interfacing) sponsored by the American Chemical Society and Virginia Polytechnic Institute and State University, in Blacksburg, Virginia, on March 21-26, 1976. Two one-day seminars on micro-computers (sponsored by *ham radio magazine*) will be given at the Dayton Hamvention, Dayton, Ohio, on April 23-24, 1976.*

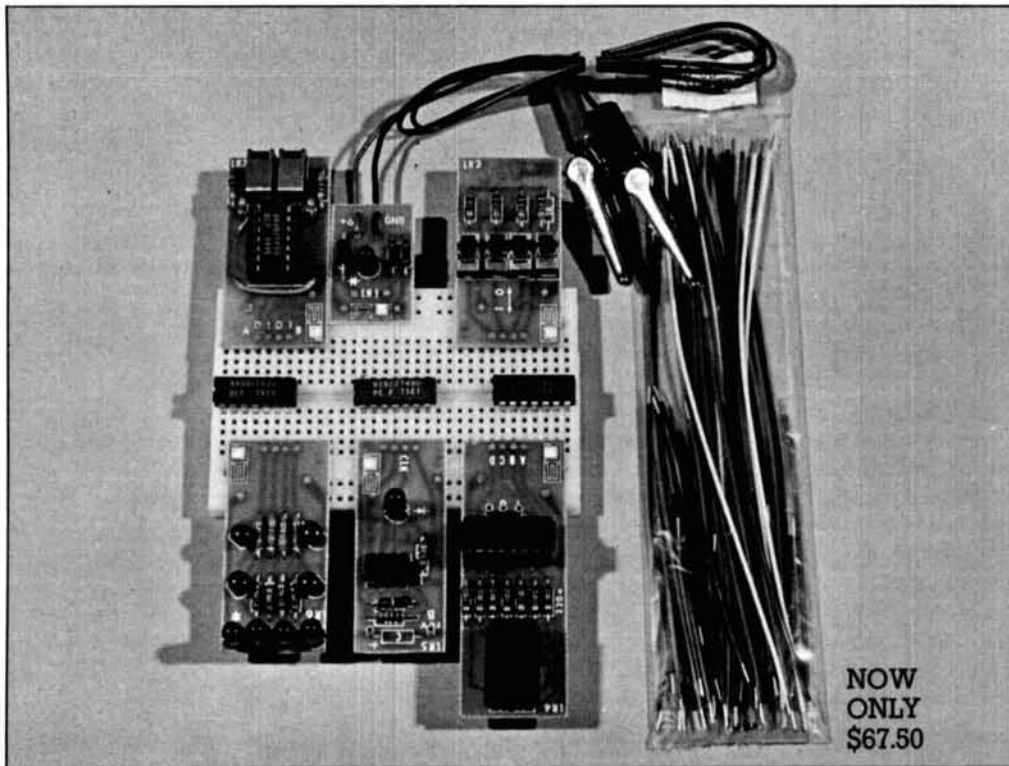
*The fee for the one-day seminar is \$50 and includes \$35 worth of books. Since the seminars are limited to 100 persons, early registration is recommended. For details write to *ham radio*, Greenville, New Hampshire 03048.

bibliography

1. David Larsen, Peter Rony and Jonathan Titus, "Bugbook III, Microcomputer Interfacing Experiments Using the Mark 80^R Microcomputer, an 8080 System," E&L Instruments, Inc., Derby, Connecticut, 1975. \$14.95 from Ham Radio Books, Greenville, New Hampshire 03048.

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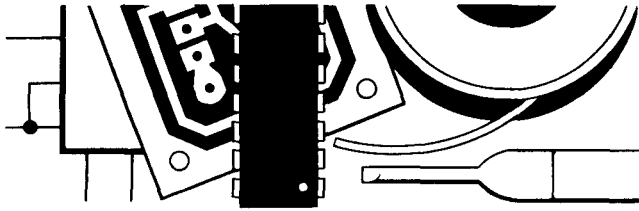
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In today's solid-state world, the variable low-voltage bench power supply is an absolute necessity for the serious experimenter. In fact, an axiom might well be that no matter how many bench supplies you have, you are always one short. And except for those amateurs who are fortunate enough to have acquired commercial power supplies, most of us are probably still using units which were built years ago and which go down to perhaps 4 or 5 volts because a reference supply would have been needed to enable the main supply to go to zero.

The relatively new RCA CA3130 operational amplifier makes possible a highly regulated power supply whose output will approach zero without a separate internal reference source. As shown in fig. 1, this op amp comprises both mos and bipolar transistors on a monolithic chip. It features a gate-protected input stage which has an input impedance of 1.5 million megohms and which is rated for typical input bias currents of 5 picoamperes¹. It also operates from a single power supply. Best of all, the single-unit price is less than \$2.00.

A power supply utilizing the CA3130 in a regulator circuit described in reference 1 has been constructed. It provides a regulated output of 0 to 40 volts at better than one ampere, and incorporates fold-back short-circuit protection. Load regulation is 0.1 percent, and line regulation is 0.02 percent for a 10-percent line-voltage change. Total noise and ripple output is less than 200 microvolts rms.

The CA3130, four discrete transistors, an inexpensive transistor array IC, and a bridge rectifier constitute the entire semiconductor complement, at a total cost of under \$11.00. Furthermore, all of the devices are available from your friendly RCA Solid State distributor, if you specify the equivalent RCA type 44002 diodes in lieu of the 1N4002s indicated in fig. 2*.

*A complete parts kit for this power supply is being made available in conjunction with this article. For ordering information and prices, write to Dentron Radio Co., Inc., 2100 Enterprise Parkway, Twinsburg, Ohio 44087, or telephone (216) 425-3173.

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

circuit description

The complete circuit of the power supply is shown in fig. 2. In this unit, T1 is a surplus transformer having a 36-volt, 2-ampere secondary. However, you can use any transformer you wish, up to 40 volts, by selecting the values of two resistors (more about this later).

The operating and reference voltages for U2, the CA3130, are established by U1, a CA3086 transistor array, which is shown in block form to simplify the schematic. A stable, low-impedance, temperature-compensated source of reference voltage is provided at pin 14 of U1. Voltage adjust control R7 determines the output voltage by setting the amplitude of the reference voltage which is applied to the inverting input (pin 2) of U2. In turn, the output of U2 supplies the base of driver transistor Q3, which controls the base current of the Darlington pair (Q1 and Q2), and hence the series pass resistance.

Let's assume that the output from the power supply starts to increase, either because of an increase in ac line voltage or a decrease in dc load current. A proportional increase appears at the junction of resistors R13 and

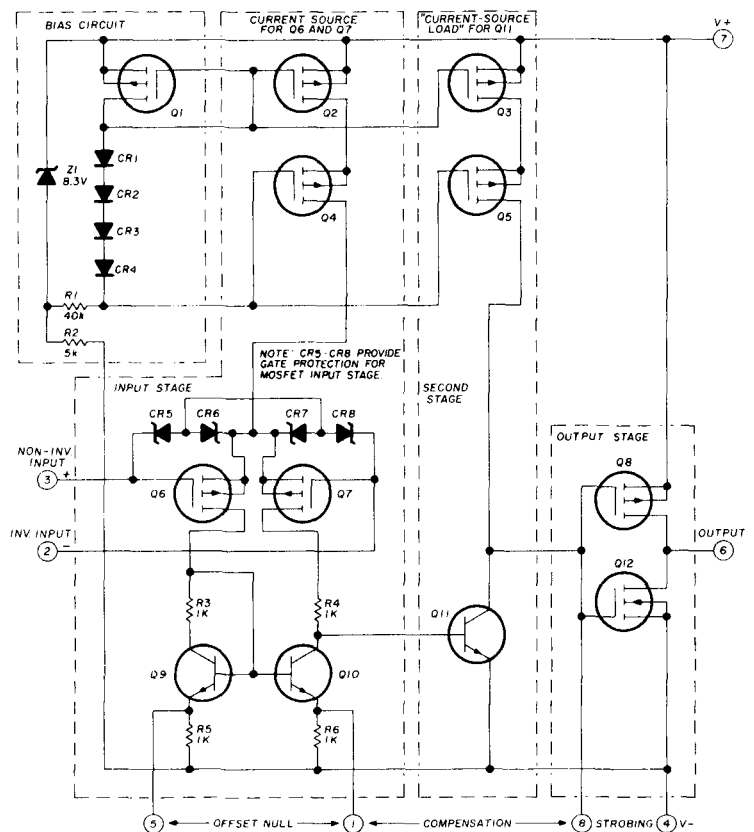


fig. 1. Schematic diagram of the RCA CA3130 op amp.

R15, and is applied to the non-inverting input (pin 3) of U2 through R14. The resultant increase in output current from U2 causes an increase in the collector current of Q3, reducing the drive to the base of Q2 and increasing the collector-to-emitter resistance of Q1. Thus the output voltage is reduced by the closed loop until it is reestablished at the value set by R7. The entire correction takes place almost instantaneously, abetted by the high gain of the op amp (approximately 110 dB) and of the loop. Conversely, if the output voltage starts to decrease, an equivalent but opposite reaction maintains the output constant.

Short-circuit protection is provided by Q4. The base-emitter voltage of Q4 is the voltage which appears across the base-emitter junction of Q1 plus the voltage drop, caused by the load current, across parallel resistors R8 and R9. When this voltage exceeds a predetermined value established by potentiometer R11, Q4 conducts and diverts current from the base of Q1, thereby limiting the short-circuit current to a safe value (approximately 500 milliamperes) and saving the series-pass transistor.

To quickly reduce the output voltage to zero when primary power is switched off, a double-pole double-throw switch is used. One pole of S1 is the conventional primary ac switch; the other pole discharges the filter capacitors through R16 when the switch is in its *off* position. A 50-volt meter is incorporated to monitor the output voltage.

Returning to the function of U1, let's examine the configuration of its transistors. Fig. 3A shows the actual circuit arrangement, while fig. 3B shows the functional circuit. Transistors Q_A and Q_B are each connected to form a zener diode, and are connected in series to provide a regulated 14-volt supply for U2.

Transistor Q_E is configured as a constant-current

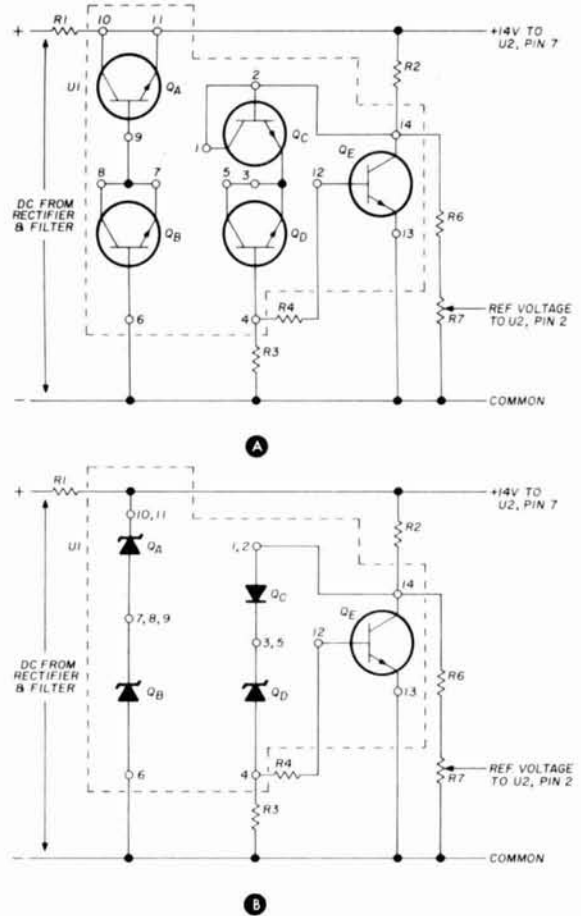


fig. 3. Circuit A is the actual dc circuit arrangement of transistor array U1, as used in fig. 2. Circuit B is the equivalent functional circuit. The numbered terminals correspond to the pin-outs on the CA3086 package.

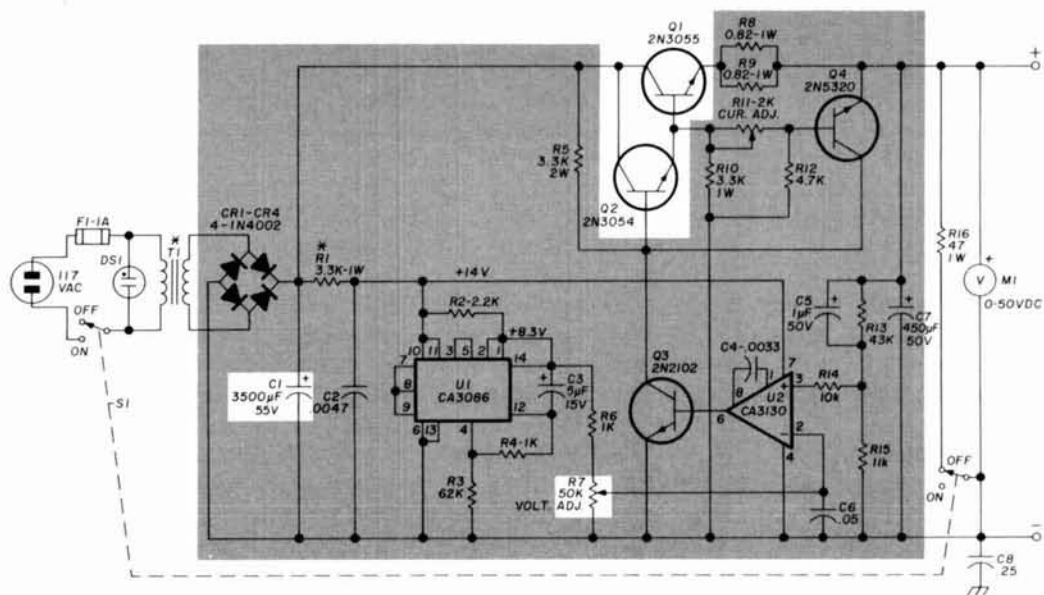


fig. 2. Schematic diagram of the regulated power supply. Parts shown within the shaded area are mounted on the printed-circuit board. Those marked with an asterisk are discussed in the text.

generator whose base bias is dropped from the collector potential by Q_C and Q_D . The latter is connected as another zener diode, while Q_C provides temperature compensation by virtue of its arrangement as a forward-biased silicon diode. This entire circuit, operating from the regulated 14-volt line, establishes a stable reference-voltage source of approximately 8.3 volts at the collector of Q_E .

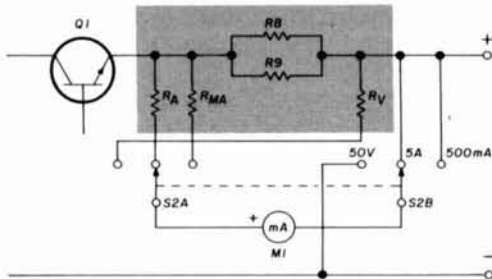


fig. 4. Voltage and current metering circuit using a single milliammeter. The values of R_A , R_{MA} , and R_V depend on the meter, and their determination is covered in the text. The switch must be a non-shorting type. Q_1 , R_8 , and R_9 are the same as in fig. 2. Parts within the shaded area are mounted on the printed-circuit board.

A portion of this voltage is applied, via R_6 and R_7 , to the inverting input of U_2 and serves as the reference for the regulator circuit.

transformer

Since it is unlikely that anyone else would have a transformer identical to the one I used in my supply, a brief discussion of the transformer is warranted. Obviously, the first requirement is that the secondary be rated for at least the maximum amount of current you expect to draw; one ampere is recommended.

The secondary voltage can be anything between 15 and 40 volts. The choice depends on the maximum dc output that you want, which will be about 5 volts less than the unregulated dc developed across filter capacitor C_1 . A good transformer will supply unregulated dc equal

to 1.4 times the secondary rms voltage at no load, and about 1.3 times the secondary rms voltage at full load.

Using these figures as the starting point, calculate a value for resistor R_1 which will drop the *estimated no-load dc voltage* to 14 volts at a current of 10 milliamperes. R_{15} will probably also require a change from the value shown in fig. 2, but this can best be done after the power supply is built and working.

voltage and current metering

Although only the voltmeter shown in fig. 2 is really necessary, it is often convenient to be able to measure the load current without having to hook up an external meter. Fig. 4 shows a simple circuit using a milliammeter and a three-position switch to allow measurement of output voltage and measurement of load current in two ranges. In order to keep the total current from passing through the switch contacts, the voltage drop across the overload-sensing resistors (R_8 and R_9) is measured, with the meter indicating the equivalent current through the resistors. The values of R_A , R_{MA} , and R_V depend on the ranges desired, the full-scale meter current, and the meter resistance; the method of calculating these values is covered in the appendix.

construction

The housing and construction of the power supply is a matter of personal preference. Naturally, for bench use, switch S_1 , pilot light DS_1 , meter M_1 , voltage control R_7 , the output terminals, and meter switch S_2 (if used) should be on the front panel. Current adjust potentiometer R_{11} can be a screwdriver-adjust or pc-board type, since it is set once and then forgotten.

Transistors Q_1 and Q_2 must be mounted on a husky heatsink — the larger the better. Remember that Q_1 passes the full load current, and dissipates power equal to this current times the voltage drop between collector and emitter. This can exceed 40 watts at low output voltages, which is a lot of heat to dissipate. Be sure to use insulators between the heatsink and the transistors,

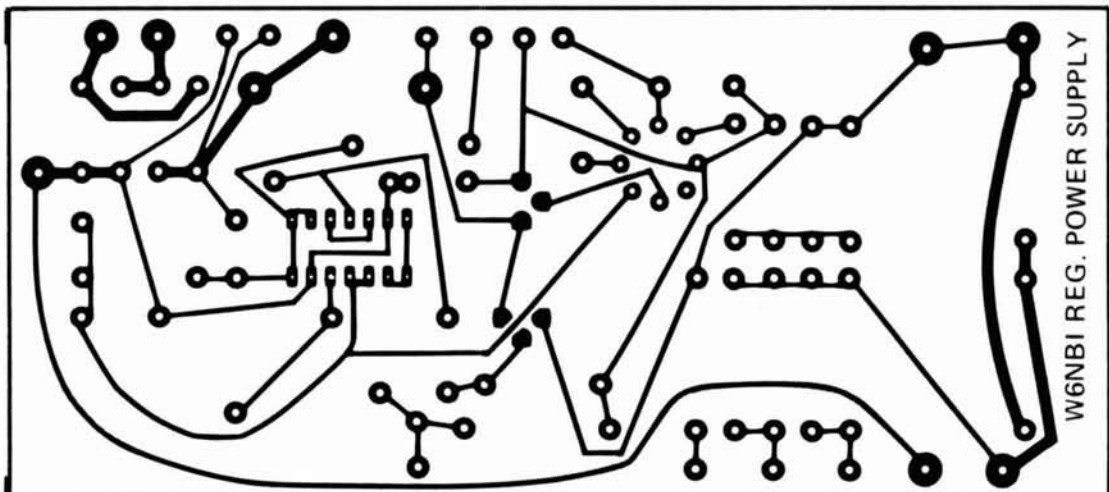


fig. 5. Foil pattern of the printed circuit board.

and to apply a thin film of silicone heat-transfer compound to each side of the insulator.

Most of the other parts are mounted on the printed-circuit board shown in figs. 5 and 6, or can be hard-wired on a piece of perf board. The pc board has been designed to accept standard available parts. R11 is a thumbwheel-type control, such as a Mallory MTC23L1 or CTS X-201-R202B. The 2.5k Radio Shack 271-228 may also be used.

maximum output voltage cannot be reached, R15 must be decreased. In either case, small changes in R15 will permit full rotation of the voltage adjustment control over the desired voltage range.

Reduce the output voltage to zero and connect a load resistance to the power supply (in series with an external ammeter if you have incorporated only the voltmeter) which will draw approximately one ampere at any output voltage over 5 volts. Monitor the load current and

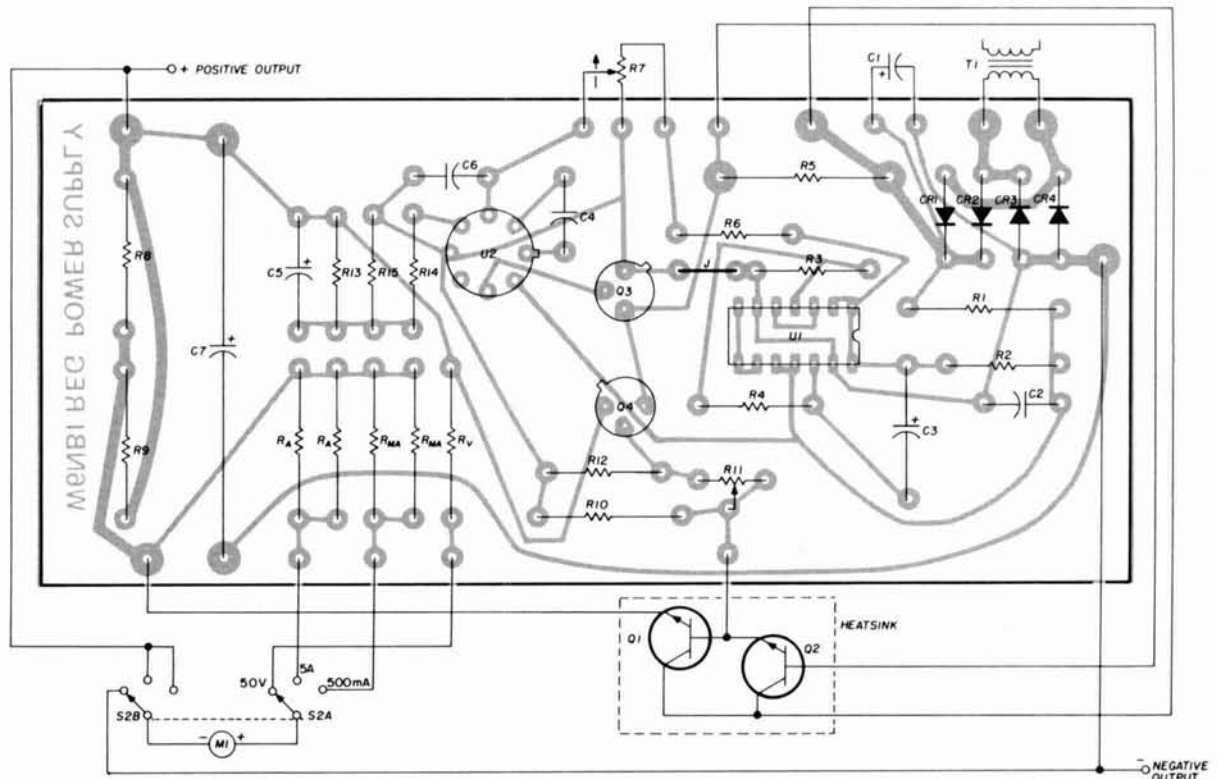


fig. 6. Component layout of the printed-circuit board. R_A , R_{MA} , and R_V are part of the optional metering circuit shown in fig. 4, and may be omitted if that circuit is not used. Note that provisions have been included for incorporating two parallel resistors for both R_A and R_{MA} , as discussed in the text. J signifies a wire jumper.

If you use the perf board, remember one thing: be certain to connect the negative terminal of filter capacitor C1 directly to the negative side of the rectifier bridge. None of the other negative returns is critical, but must not be between the capacitor and the rectifier. Failure to wire this or any other high-current power supply in the prescribed manner will result in excess ripple in the output.

adjustment and test

After all wiring has been checked, set voltage adjustment control R7 to minimum and current adjustment potentiometer R11 to mid-range. Apply ac power and monitor the output voltage while rotating the voltage adjustment control to maximum. The output voltage should increase smoothly. If it reaches a maximum before the control is fully rotated, the value of R15 must be increased. On the other hand, if the desired

gradually increase the output to one ampere. If you cannot obtain enough current, readjust pot R11 slightly. Check the output voltage as the load resistance is disconnected and reconnected; there should be no discernable voltage change.

Once more reduce the output voltage to zero and set R11 for minimum resistance between the base of Q1 and the base of Q4. Disconnect the load resistance and short-circuit the output terminals if you have built the ammeter circuit into the power supply. Otherwise connect an external ammeter (1 amp or more) directly across the output terminals. Slowly increase the setting of the voltage adjustment control, and adjust R11 for a short-circuit current between 450 and 500 milliamperes.

Finally, check the value of R1 by measuring the voltage across it under no-load conditions, and calculate the current flowing through it. The calculated current should be approximately 10 milliamperes. If it is over 11

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or less than 9 milliamperes, change R1 to obtain a value of current closer to 10 milliamperes.

That completes the project. If you want to check the regulation, you will need a digital or differential voltmeter, since a 0.1-percent change is measured in millivolts. Noise and ripple output can be checked with either a high-sensitivity scope or with a good ac electronic voltmeter, such as a Hewlett-Packard 400D, capable of reading 1 millivolt full scale. If you have test equipment of this type, have at it. Otherwise, forget about it and make a new addition to your bench — you can always use one more power supply.

appendix

Calculation of resistance values for R_A , R_{MA} , and R_V in fig. 4 must be based on the following known factors: the exact parallel resistance of R8 and R9, the internal resistance (R_m) of the meter, and the full-scale meter current (I_m). The meter characteristics generally are known or can be measured. However, the parallel resistance of R8 and R9 must be accurately known or measured on a bridge (not calculated from the nominal resistance values), or an external ammeter must be used for calibration.

The value of R_V can be calculated from the equation

$$R_V = \frac{E_{fs} - (I_m R_m)}{I_m}$$

where E_{fs} is the desired full-scale voltage.

The value of R_A (or R_{MA}) is determined by the equation

$$R_A = \frac{(I_L R_{8-9}) - (I_m R_m)}{I_m}$$

where I_L is the load current corresponding to full-scale meter current and R_{8-9} is the parallel resistance of R8 and R9.

As an example, assume that the meter ranges in fig. 4 are to be obtained with a 1-mA meter having an internal resistance of 100 ohms.

Using the preceding equations,

$$R_V = \frac{50 - (.001 \times 100)}{.001} = 49,900 \text{ ohms}$$

$$R_A = \frac{(5 \times .41) - (.001 \times 100)}{.001} = 1950 \text{ ohms}$$

$$R_{MA} = \frac{(.5 \times .41) - (.001 \times 100)}{.001} = 105 \text{ ohms.}$$

The meter will be sufficiently accurate if one-percent resistors are used to obtain these values. However, if the actual resistance of R8 and R9 in parallel was not known, and the nominal value was used to calculate the values of R_A and R_{MA} , the current ranges may be off by 5 to 10 percent, depending on the actual resistances of R8 and R9. This can be improved if a more accurate ammeter is available. Instead of using the calculated values of R_A and R_{MA} , use one-percent resistors which are approximately ten percent higher than the calculated values. Then connect the external ammeter in series with a load and compare the currents read on the external and internal meters. You can expect the internal meter to read low. Increase its reading by connecting a composition resistor in parallel with R_A (or R_{MA}). Start with one that has about ten times the resistance of the one-percent resistor, and keep trying different values until the two meters agree.

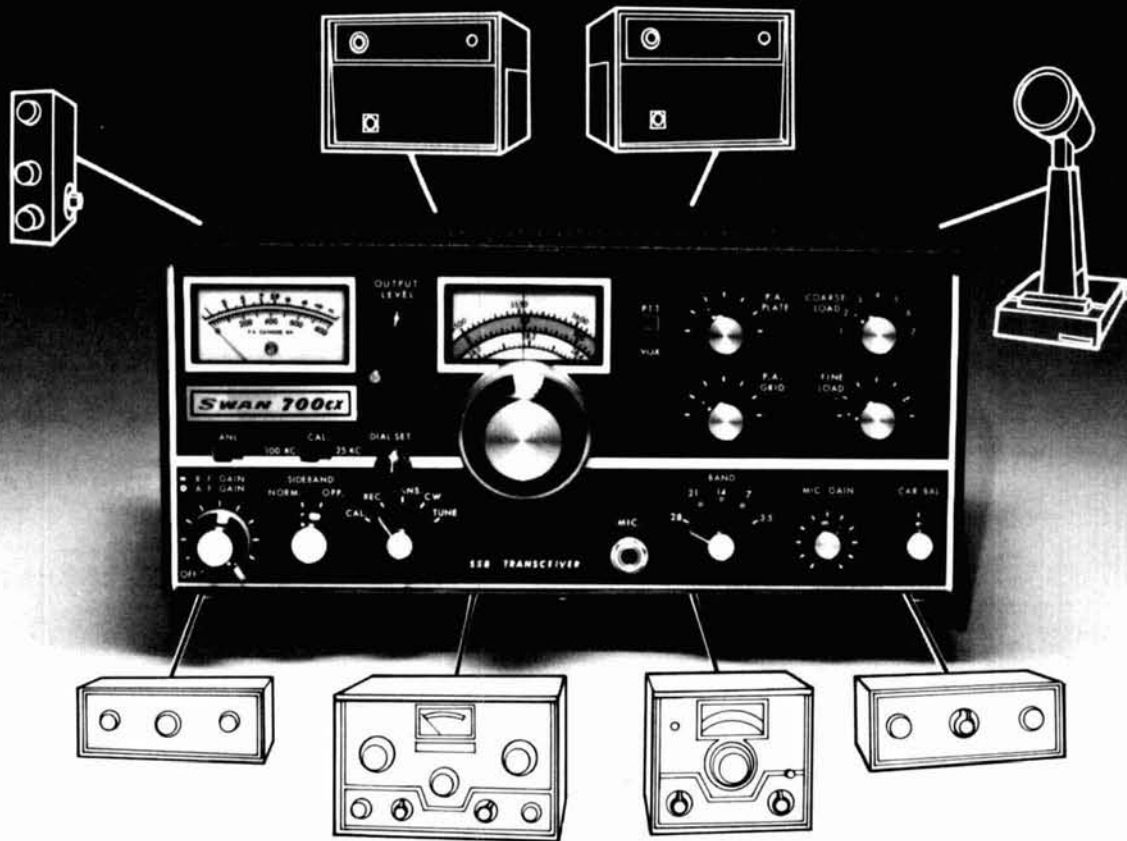
You can select any meter ranges that you feel are convenient, and then change the meter scale accordingly. I have found that the markings on most scales can be erased with a pink (not white grit) pencil-type typewriter eraser. New numbers can then be applied, using rub-on transfers.

reference

1. Data Sheet for CA3130 Series COS/MOS Operational Amplifiers, File Number 817, RCA Solid State Division, Somerville, New Jersey 08876, August, 1974.

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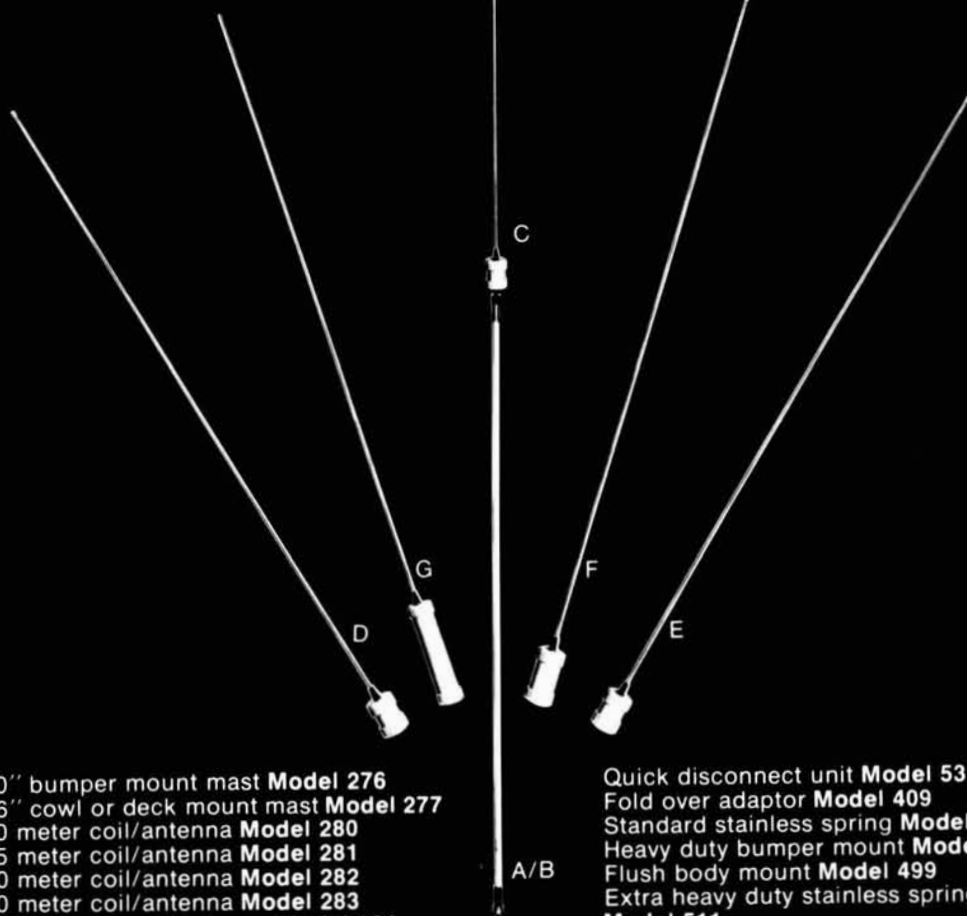
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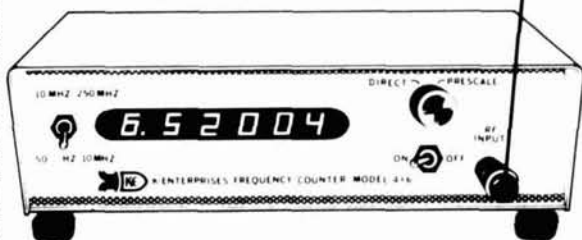
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the ham notebook

another look at the fm channel scanner for the Heath HW202

The scanner adaptation article by Ken Stone, W7BZ, in the February, 1975, issue of *ham radio* was a good one. (The original article, by K2ZLG, appeared in the February, 1973, issue.) I'd like to add some words on my experience with this circuit.

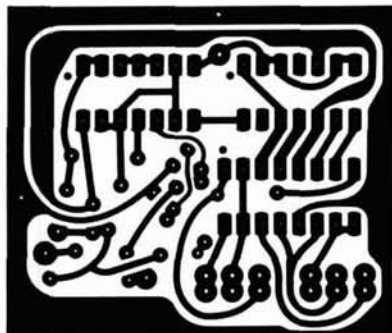


fig. 1. Circuit-board layout for the f-m scanner.

I wanted to have the scanner and the tone-burst encoder mounted *inside* the HW202 without the *inconvenience* and add-on appearance of outboard hardware. So I made the circuit board shown in fig. 1 for the scanner, which fits inside the HW202 just under the tone-burst encoder and just above the speaker.

Parts are hard to get in this area. The 7445 was replaced with a 7441, and all outputs were connected so the unit would scan in both directions. The 2N4140s were replaced with 2N2222s. The LEDs were cemented into small

holes punched on either side of the tone-burst encoder knobs. Two of the same colored wires, about 8 inches (20.3cm) long, were soldered as close as possible to the LEDs.

A notch was made on the upper side of the hole where the tone-burst encoder shaft passes through the metal plates behind the knobs. This notch allowed enough room for the wires to pass over the switches and through the holes without binding. With the tone-burst encoder remounted, an area about 2-1/8 by 1-3/4 inches (54 by 45mm) was available for mounting a PC board for the scanner.

All scanner components were first mounted on a breadboard and all wiring was connected without cutting off any excess. This breadboard version was a good idea, because initial checks indicated some problems — the LEDs didn't agree with the channels below them. Make sure you check out the circuit before you button it up.

The PC board shown in fig. 1 looks somewhat unorthodox, but when no-

body is around to tell you how, you do the best you can. Note that the letter J appears several times in the PC-board illustration. This means that a jumper must be connected between the points shown. Make sure you install the jumper under the 7441 before you mount the device, otherwise you'll have to install an insulated jumper on the foil side. Also note that pin 10 must be clipped from the 7490 or it can't be mounted. Finally, leave wire lengths longer than necessary to facilitate knob removal of the tone-burst encoder.

Bill Biser, K7PYS

variable, low-cost power supply for transistor work

If you like to work with transistors and ICs, troubleshoot transistor radios, receivers, walkie-talkies, or are tired of buying batteries for low-power experimental work, this variable power supply may be the answer.

As this is a simple, low cost, one-evening project, only the essential features are described. You may want to add refinements of your own which will make the power supply more responsive to your own specific needs. Although I made no measurements of the output regulation, it appears adequate for the intended purposes.

The heart of this power supply are ac adapter units which are also known as battery eliminators, solid-state dc power supplies, power converters, etc. These adapters can be found at flea markets, hamfests and junk shops at bargain prices. I paid fifty cents each for mine. One unit alone could have been used in the circuit of fig. 3 although two are preferable for 12 or 18 volts output.

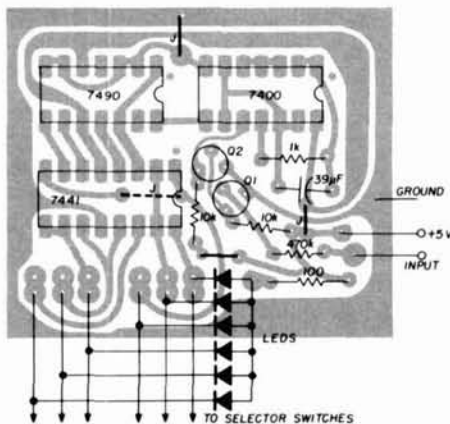


fig. 2. Component layout for the fm scanner board. Letter J designates a jumper.

The two adapters I used had the following information imprinted on the cover:

120 Vac	9 Vdc, 40 mA
60 Hz	or
5 W	6 Vdc, 230 mA

Since I wondered how you got 6 V dc at 230 mA from a sealed unit whose

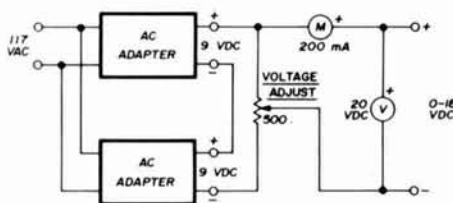


fig. 3. Simple, low-current power supply is based on the use of ac adapters or battery eliminators which are often found at flea markets.

actual output was 9 Vdc, I wrote to the manufacturer. They replied that "This power converter is intended to be used with our products at these voltages and current ratings." From this I concluded that the unit was capable of giving 6 volts at the prescribed current but that I would have to supply my own voltage-dropping resistor. All of this is not too pertinent except to point out that you should read the manufacturer's label and be sure to measure the voltage output. The important specification is the wattage rating of 5 watts — this is adequate for a low-current power supply.

These ac adapters usually consist of a small step-down transformer, full-wave rectifier (often selenium) and capacitor input filtering. The circuit is often on a printed-circuit board and is contained in a tightly sealed plastic box.

There is nothing critical in power supply layout or wiring. Be sure to insulate the binding posts from the chassis, at least the plus lead. In addition to the two ac adapters you need two panel meters, a toggle switch, a 500-ohm potentiometer, duplex wall outlet for 117 Vac, two binding posts, and an ac plug and line cord. The meters, switch

and binding posts are mounted on the front panel. The duplex wall outlet is installed on the chassis from underneath. Since most of the ac adapters have plugs integrally molded into the housing, they can be plugged directly into the duplex outlet on the chassis. The output of the power supply I built is about three-quarters of a watt with voltage control from zero to 18 Vdc.

A word about the meters. Although I used 50 Vdc and 300 mA meters I had in my junk box, a 0-20 Vdc voltmeter and a 0-100 or 0-200 milliamperere meter would be preferable.

Howard Stark, WA4MTH

microwave frequency doubler

As spectrum space becomes more and more valuable, amateurs are forced to explore the communication possibilities of the microwave bands. Klystrons and other exotic devices have been available since the late forties for use as high as 12 GHz with modifications, but there are few components available for the next higher amateur band (24 GHz), either surplus or commercial. This article describes a simple frequency doubler to get from 12 GHz to 24 GHz in one noncritical step. The step is made with an ordinary point-contact diode, a 1N23.

As most amateurs are aware, if a

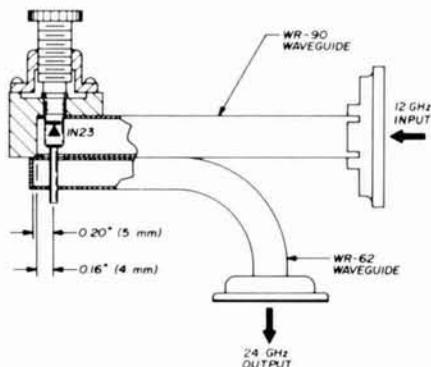
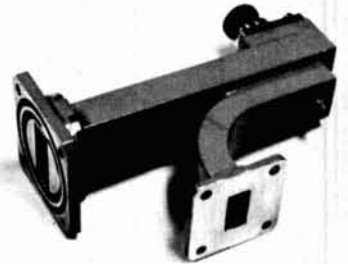


fig. 4. Microwave 12 to 24 GHz frequency doubler uses 1N23 point-contact diode. Only critical dimensions are spacing of the diode from the shorted ends of the waveguides.



Microwave frequency doubler provides 5 Mw output at 24 GHz with 100 mW input at 12 GHz. Fundamental is suppressed 23 dB.

diode is driven by an alternating current source, harmonics will be generated but the strength falls off with increasing harmonic number. Here only the second harmonic is used which is 13 dB down from the fundamental. The third harmonic is an additional 20 dB down so it can be ignored (or filtered out if you are a purist).

The diode cartridge is mounted in an untuned waveguide section as illustrated in fig. 4. The input waveguide is a short section of WR-90 guide, 1 by 0.5 inch (2.54 by 1.22cm) nominal. The output guide is type WR-62, 0.7 by 0.35 inch (1.78 by 0.89cm) nominal. By the way, the WR classification gives the largest inside dimension of the guide. For example, the inside width of WR-90 is 0.9 inches; the inside width of WR-62 is 0.622 inches.

The only dimensions which should be adhered to closely in the construction of the doubler is the spacing of the diode from the shorted ends of the waveguides. The tolerance here is ± 0.04 inch (± 1 mm).

In use, an 12-GHz klystron, such as a X-13, is connected to the input flange and 24-GHz energy will exit the output port. As previously mentioned, the system loss for a drive level of 100 mW is 13 dB. The fundamental is down 23 dB. The diode presently being used has withstood 350 mW of drive for over 200 continuous hours with no degradation in performance.

John Franke, WA4WDL

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- Weight: 5 1/2 lbs.
- Power Requirements:
 - Source: 13.5 VDC ± 10%
 - Receive: .45A
 - Transmit: 2.6A (10W), .7A (1W)

SPECIAL INCLUDES:

- WILSON "WE-224"
- MOBILE MIKE
- MOUNTING BRACKET
- 146, 52/52 SIMPLEX
- TWO PAIR TX/RX CRYSTALS OF YOUR CHOICE. (Common Repeater Frequency only)

SPRING Special on Wilson Hand Held 220 and 450

2202 SM

FREQUENCY RANGE 220 - 225 MHz

- 6 Channel Operation
- Individual Trimmers on all TX/RX Crystals
- All Crystals Plug In
- 12 KHz Ceramic Filter
- 10.7 and 455 KC IF
- .3 Microvolt Sensitivity for 20 Db Quieting
- Weight: 1 lb. 14 oz. less Battery
- Battery Indicator
- Size: 8 7/8 x 1 3/4 x 2 7/8
- Switchable 1 & 2.5 Watts Output @ 12 VDC
- Current Drain: RX 14 MA TX 500 MA
- Microswitch Mike Button
- Unbreakable Lexan® Case

USES SAME ACCESSORIES AS 1405

INTRODUCTION SPECIAL

\$239⁹⁵

INCLUDES

- 2202 SM
- Flex Antenna
- 223.50 Simplex Installed



4502 SM

FREQUENCY RANGE 420 - 450 MHz

- 6 Channel Operation
- Individual Trimmers on all TX/RX Crystals
- All Crystals Plug In
- 12 KHz Ceramic Filter
- 10.7 and 455 KC IF
- .3 Microvolt Sensitivity for 20Db Quieting
- Weight: 1 lb. 14 oz. less Battery
- Battery Indicator
- Size: 8 7/8 x 1 3/4 x 2 7/8
- Switchable 1 & 1.8 Watts Output @ 12 VDC
- Current Drain: RX 14 MA TX 500 MA
- Microswitch Mike Button
- Unbreakable Lexan® Case

USES SAME ACCESSORIES AS 1405

INTRODUCTION SPECIAL

\$269⁹⁵

INCLUDES

- 4502 SM
- Flex Antenna
- 446.00 Simplex Installed

HAND HELD ACCESSORY SPECIALS

DESCRIPTION	SPECIAL PRICE
BC1 - BATTERY CHARGER	\$29.95
BP - NI-CAD BATTERY PACK	10.95
LC1 - 1402 LEATHER CASE	8.50
LC2 - LEATHER CASE FOR 1405, 2202, 4502	8.50
SM2 - SPEAKER MIKE FOR 1402 AND 1405	24.95
TE1 - SUB-AUDIBLE TONE ENCODER INSTALLED	34.95
TTP - TOUCH TONE PAD INSTALLED	44.95
XF1 - 10.7 MONOLITHIC IF XTAL FILTER INST.	8.95
CRYSTALS: TX OR RX (Common Freq. Only)	3.00



BC - 1 BATTERY CHARGER

NOTE: ACCESSORY SPECIAL PRICE AVAILABLE ONLY AT TIME OF RADIO PURCHASE

Wilson Electronics Corp.

FACTORY DIRECT

SPRING SPECIAL

1402SM
HAND HELD
2.5 WATT
TRANSCEIVER
144-148 MHz

\$164⁹⁵



Optional
Touch-Tone Pad
Shown

FEATURES

1402 SM

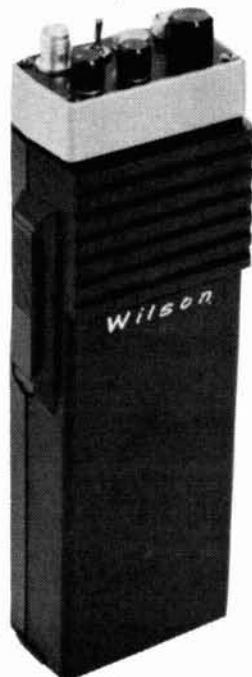
- 6 Channel Operation
- Individual Trimmers on all TX/RX Crystals
- All Crystals Plug In.
- 12 KHz Ceramic Filter
- 10.7 IF and 455 KC IF
- .3 Microvolt
- Sensitivity for 20 dB Quieting
- Weight: 1 lb. 14 oz. less Battery
- S-Meter/Battery Indicator
- Size: 8 7/8 x 1 7/8 x 2 7/8
- 2.5 Watts Minimum Output @ 12 VDC
- Current Drain RX 14 MA TX 500 MA
- Microswitch Mike Button

1405 SM

- 6 Channel Operation
- Individual Trimmers on all TX/RX Crystals
- All Crystals Plug In
- 12 KHz Ceramic Filter
- 10.7 and 455 KC IF
- .3 Microvolt
- Sensitivity for 20 dB Quieting
- Weight: 1 lb. 14 oz. less Battery
- Battery Indicator
- Size: 8 7/8 x 1 3/4 x 2 7/8
- Switchable 1 & 5 Watts Minimum Output @ 12 VDC
- Current Drain: RX 14 MA TX 400 MA (1w) 900 MA (5W)
- Microswitch Mike Button
- Unbreakable Lexan® Case

1405SM
HAND HELD
5 WATT
TRANSCEIVER
144-148 MHz

\$239⁹⁵



SPECIAL ON EACH RADIO INCLUDES:

Flex Antenna
52/52 Simplex Xtal

Can be Modified
for
MARS or CAP

10 Day
Money Back
Guarantee

90
Day
Warranty

TO: WILSON ELECTRONICS CORP., 4288 S. POLARIS AVE., LAS VEGAS, NEVADA 89103
(702) 739-1931

SPRING SPECIAL DIRECT SALE ORDER BLANK

_____ 2202 SM @ \$239.95. _____ 4502 SM @ \$269.95. _____ WE-224 @ \$199.95.

_____ 1402 SM @ \$164.95. _____ 1405 SM @ \$239.95.

Accessory Special Prices Available Only at Time of Radio Purchase.

_____ BC1 @ \$29.95. _____ BP @ \$10.50. _____ LC1 @ \$8.50. _____ LC2 @ \$8.50.

_____ SM2 @ \$24.95. _____ TE1 @ \$34.95. (SPECIFY FREQUENCY _____)

_____ TTP @ \$44.95. _____ XF1 @ \$8.95. _____ TX or RX XTALS @ \$3.00 ea. _____ INSTALL XTALS @ \$7.50/Radio.

EQUIP TRANSCEIVER AS FOLLOWS: XTALS A. _____ B. _____

C. _____ D. _____ E. _____ F. _____

ENCLOSED IS _____ CHECK MONEY ORDER MC BAC

CARD # _____ EXPIRATION DATE _____

NAME _____

ADDRESS _____

CITY _____ STATE _____ ZIP _____

SIGNATURE _____

SHIPPING & HANDLING PREPAID FOR SPRING SPECIAL

VALID ONLY MARCH 1-31, 1976

HR

NEVADA RESIDENTS ADD SALES TAX

Ham it up for \$3.95.



Amateur crystals 144.0-148.00 only for this trim price, plus 25¢ per crystal for handling and postage. Florida residents add 4% sales tax. Send frequencies, make and model when ordering. Our price includes most gear on our free Parts List. For equipment not listed, we'll provide prices on request and slice up something special. Master Charge and BankAmericard telephone orders accepted. No C.O.D.s.



Savoy Electronics Inc.

P.O. Box 5727, Fort Lauderdale, Florida 33310
305/563-1333

Manufacturers of Quality Quartz Crystals Since 1937

POLICE CALL

FREQUENCIES/CALL LETTERS/AREAS OF OPERATION

- Police
- Ambulance
- Rescue Squad
- Fire
- Paramedic
- Government

COMPLETELY REVISED & EXPANDED: 30,000 ADDITIONS & CHANGES

1976 Edition (Green Cover)

• 9 VOLUMES NOW AVAILABLE

- PRICE.....\$ 4.95 per volume, plus postage and handling
1.00 per volume for first class or
.30 per volume for fourth class.
New Jersey residents - add 25¢ sales tax
per volume.

- VOLUME 1 Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island, Vermont
- VOLUME 2 Delaware, Maryland, New Jersey, Pennsylvania
- VOLUME 3 Ohio, Michigan
- VOLUME 4 Illinois, Indiana, Kentucky, Wisconsin
- VOLUME 5 Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, South Dakota
- VOLUME 6 District of Columbia, Florida, Georgia, North Carolina, South Carolina, Virginia, West Virginia
- VOLUME 7 Alabama, Arkansas, Louisiana, Mississippi, Oklahoma, Tennessee, Texas
- VOLUME 8 Arizona, Colorado, Idaho, Montana, New Mexico, Nevada, Utah, Wyoming
- VOLUME 9 California, Oregon, Washington

Bonus Features

- Operating Details of Many Major Systems
- FCC Allocation List of 1800 Frequencies

SPECIAL: All 9 Volumes \$39.00 (Includes 1st Class Postage)

Send Money Order or Check to

POLICE CALL
LEBANON, NEW JERSEY 08833

ME-3 microminiature tone encoder

Compatible with all sub-audible tone systems such as: Private Line, Channel Guard, Quiet Channel, etc.

- Powered by 6-16vdc, unregulated
- Microminiature in size to fit inside all mobile units and most portable units
- Field replaceable, plug-in, frequency determining elements
- Excellent frequency accuracy and temperature stability
- Output level adjustment potentiometer
- Low distortion sinewave output
- Available in all EIA tone frequencies, 67.0 Hz-203.5 Hz
- Complete immunity to RF
- Reverse polarity protection built-in



\$29.95 each

Wired and tested, complete with K-1 element

communication specialists

P. O. BOX 153
BREA, CALIFORNIA 92621
(714) 998-3021

K-1 FIELD REPLACEABLE, PLUG-IN, FREQUENCY DETERMINING ELEMENTS
\$3.00 each

7400N TTL			
SN7400M	13	SN7453N	27
SN7401N	16	SN7454N	41
SN7402N	21	SN7455N	25
SN7403N	16	SN7456N	22
SN7404N	16	SN7457N	45
SN7405N	24	SN7471M	69
SN7406N	45	SN7472M	39
SN7407N	45	SN7473M	37
SN7408N	25	SN7474M	32
SN7409N	25	SN7475M	59
SN7410N	16	SN7476M	32
SN7411N	30	SN7477M	5.00
SN7412N	42	SN7480N	50
SN7413N	86	SN7481N	1.75
SN7414N	70	SN7483N	1.15
SN7415N	43	SN7485N	1.12
SN7417N	43	SN7486N	45
SN7418N	25	SN7488N	3.50
SN7420N	21	SN7489N	3.00
SN7421N	39	SN7490M	49
SN7423N	37	SN7491N	1.20
SN7425N	43	SN7492N	82
SN7426N	31	SN7493M	57
SN7427N	37	SN7494N	91
SN7429N	42	SN7495N	91
SN7430N	26	SN7496N	91
SN7432N	31	SN7497M	4.00
SN7437N	47	SN74100M	1.00
SN7438N	40	SN74107N	49
SN7439N	25	SN74121M	45
SN7440N	21	SN74122N	49
SN7441N	1.10	SN74123M*	89
SN7442N	1.08	SN74125M	60
SN7443N	1.05	SN74126N	.81
SN7444N	1.10	SN74132N	3.00
SN7445N	1.10	SN74133N	1.80
SN7448N	1.15	SN74141N	1.15
SN7447M	.79	SN74142M*	4.00
SN7448N	99	SN74143M*	4.50
SN7450N	99	SN74144M*	4.50
SN7451N	27	SN74145N*	6.00
SN7452M*	27	SN74147N	3.00

JAMES MARCH SPECIALS
Astrisk Denotes Items On Special For This Month

Special Requested Items

RC194	Dual Track V reg	\$ 5.95	M8197	\$ 3.00	MK5007	\$10.95	MC4044	4.50
RC4195	-15V Track Reg	3.25	40Z4P	2.25	8263	5.95	LM3909	1.95
F9388	Decoder	3.95	DM5130	3.25	8377	2.75	MM5320	19.95
LD1101/11	DVM Chip Set	28.00	8222	1.30	8286	1.15	4072AE	4.5
CA1310	Super CMOS Op Amp	1.49	MC14016	.56	8262	3.00	7422	1.50
MC1408L7	D/A	9.95	2525	6.00	8880	1.35	7497	5.00
F341	FIFO	6.95	2527	5.00	451AE	2.50	74186	5.00
MM5841	Character Gen.	10.00	SD415	2.50	Y84136	2.00	74279	.90

WE'LL BE HAPPY TO QUOTE ON YOUR SPECIAL PARTS -

74LS00 TTL			
74LS00	39	74LS55	.38
74LS01	39	74LS72	.65
74LS02	39	74LS74	.65
74LS04	45	74LS75	.75
74LS05	45	74LS76	.65
74LS08	39	74LS83	.25
74LS10	39	74LS86	.62
74LS13	79	74LS90	1.25
74LS14	219	74LS92	1.25
74LS20	39	74LS93	.25
74LS26	49	74LS99	2.15
74LS27	49	74LS96	1.89
74LS28	49	74LS107	.65
74LS30	39	74LS112	.65
74LS32	49	74LS132	1.55
74LS40	49	74LS136	.65
74LS51	39	74LS138	1.89

XCITON OPTO ELECTRONICS
R - RED
G - GREEN
Y - YELLOW
O - ORANGE

LITRONIX MONSANTO DISCRETE LEDS

.125" dia.	.185" dia.	.190" dia.
XC209R 5/S1	XC256R 5/S1	XC111R 5/S1
XC209G 4/S1	XC256G 4/S1	XC111G 4/S1
XC209Y 4/S1	XC256Y 4/S1	XC111Y 4/S1
XC209O 4/S1	XC256O 4/S1	XC111O 4/S1

.200" dia.	.200" dia.	.085" dia.
XC22R 5/S1	XC256R 5/S1	MV50
XC22G 4/S1	XC256G 4/S1	085 dia Micro
XC22Y 4/S1	XC256Y 4/S1	red led
XC22O 4/S1	XC256O 4/S1	6/S1

DIP SWITCH
These switches feature four SPST Rooter Switches in a moldip die. They are ideally suited for microprocessor applications. **\$.195**

MINIATURE TOGGLE

DPST	ON	OFF	ON	OFF	ON	OFF	ON	OFF
221	2.06	2.06	1.87	1.78				
223	2.06	2.28	1.68	1.81				
121	2.36	1.98	1.43	1.30				
123	2.06	1.66	1.21	1.10				

PUSH BUTTON

Model 1 1 Quantity net prices

Number	Each	2-9	10-29	30-99	
Model 1	Each	\$1.95	\$1.47	\$1.30	
Model 2	Each	\$2.35	\$1.95	\$1.47	\$1.30

Model 2 10 Position 3.30
Model 2 10 Position 3.30
Model 2 10 Position 3.30

MANY OTHERS AVAILABLE ON REQUEST
20% Discount for 100 Combined 7400's

CMOS

CD4000	25	CD4029	2.90	74C04N	75
CD4001	25	CD4030	65	74C10N	65
CD4002	25	CD4033	1.85	74C20N	65
CD4003	2.50	CD4040	2.45	74C23N	65
CD4007	25	CD4042	2.50	74C29N	2.15
CD4009	59	CD4044	2.75	74C59N	2.50
CD4010	59	CD4045	1.90	74C59N	3.00
CD4011	25	CD4046	2.51	74C107N	1.25
CD4012	25	CD4047	2.75	74C107N	1.25
CD4013	47	CD4048	79	74C133N	2.50
CD4015	56	CD4049	1.15	74C133N	2.50
CD4017	1.35	CD4051	2.95	74C154	3.00
CD4019	55	CD4052	2.95	74C157	2.15
CD4020	1.49	CD4059	3.25	74C160	3.25
CD4022	1.25	CD4066	1.75	74C161	3.25
CD4023	25	CD4068	.45	74C163	3.00
CD4024	1.50	CD4071	.45	74C164	3.25
CD4025	25	CD4081	.45	74C173	2.60
CD4027	.69	74C020N	.39	74C193	2.75
CD4028	1.85	74C028N	.59	74C195	2.75

DISPLAY LEDS

TYPE	POLARITY	HT	TYPE	POLARITY	HT
MAN 1	COMMON ANODE	270	MAN 74	COMMON CATHODE	300
MAN 2	5 x 7 DOT MATRIX	300	DL707	COMMON ANODE	300
MAN 3	COMMON CATHODE	175	DL747	COMMON ANODE*	300
MAN 4	COMMON CATHODE	187	DL750	COMMON ANODE*	600
MAN 5	COMMON ANODE	300	DL338	COMMON CATHODE	110
MAN 6	COMMON ANODE	300	FD707	COMMON CATHODE	250
MAN 7	COMMON ANODE-GREEN	300	FD503	COMMON CATHODE	500
MAN 7Y	COMMON ANODE-YELLOW	300	FD507	COMMON ANODE	500
MAN 7Z	COMMON ANODE	300			

THUMBWHEEL SWITCHES

Part No.	Description	Price	Part No.	Description	Price
SR 1P	End Plate (each)	.50	SR 1P	End Plate (each)	.50
SR DP	Duverter Plate (each)	.40	SR DP	Duverter Plate (each)	.40
SR BB	Blank Body (each)	.40	SR BB	Blank Body (each)	.40
SR HB	Half Body (each)	.40	SR HB	Half Body (each)	.40

LINEAR

LM100H	15.00	LM1310N	2.95
LM100H	2.50	LM1351N	1.85
LM1711H	3.75	LM1414N	1.75
LM212H	7.00	LM1458C	1.65
LM300H	80	LM1496N	.95
LM301H*	3/100	LM1969N	1.85
LM301C*	3/100	LM1971N	1.95
LM302H	75	LM3822N	1.80
LM304H	80	LM3906M	2.95
LM305H	95	LM3906M	2.95
LM307C	39	NE510A	6.00
LM308H	1.00	NE511H	3.00
LM308N	1.00	NE536T	1.85
LM309H	1.10	NE540N	1.00
LM309N	1.25	NE550N	7.00
LM320K	1.15	NE550N	2.50
LM311H	.90	NE565H*	99
LM311N	.90	NE565N	4.95
LM318N	1.50	NE566N*	1.25
LM319N	1.30	NE567H*	1.25
LM319N	9.00	NE567N*	1.50
LM320K-5	1.35	LM7030N	45
LM320K-12	1.35	LM7031N	29
LM320K-15	1.35	LM7032N	79
LM320T-5	1.75	LM7110N	39
LM320T-8	1.75	LM7123N	55
LM320T-12	1.75	LM723H	55
LM320T-15	1.75	LM723N	1.00
LM323K-5*	16.00	LM730N	1.29
LM324N	1.80	LM741C*	3/100
LM339N	1.70	LM741C*	3/100
LM340K-5	1.95	LM741C*	3/100
LM340K-12	1.95	LM747N	79
LM340K-15	1.95	LM747N	79
LM340K-24	1.95	LM748H	39
LM340T-8*	1.75	LM748H	39
LM340T-15*	1.75	LM1309N	90
NE560B*	5.00	LM1304N	1.19
NE561B*	5.00	LM1305N	1.40
NE562B*	5.00	LM1307N	85

IC SOLDAIRTAI - LOW PROFILE (TIN) SOCKETS

8 pin	1-24	25-49	50-100	24 pin	1-24	25-49	50-100
14 pin	\$1.17	16	15	36 pin	\$.38	.37	.36
16 pin	20	19	18	40 pin	1.59	1.26	1.15
18 pin	22	21	20	48 pin	5.00	4.44	4.30
20 pin	29	28	27	56 pin	6.00	5.98	5.80
22 pin	37	36	35	64 pin	6.30	6.2	6.1

SOLDAIRTAI STANDARD (TIN)

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

SOLDAIRTAI STANDARD (GOLD)

8 pin	\$.30	27	.24	24 pin	\$.70	.63	.57
14 pin	35	32	29	28 pin	1.10	1.00	.90
16 pin	38	35	32	36 pin	1.75	1.50	1.45
16 pin	38	35	32	40 pin	1.75	1.59	1.45

WIRE WRAP SOCKETS (GOLD) LEAD #3

10 pin	\$.45	41	.37	24 pin	\$1.05	.95	.85
14 pin	39	38	37	28 pin	1.40	1.25	1.10
16 pin	43	42	41	36 pin	1.59	1.45	1.30
18 pin	75	68	62	40 pin	1.75	1.55	1.40

8 POSITION ROTARY SWITCH
These switches are a 7 position, one position open, rotary switch enclosed in a TO-5 can. They have a standard 8 pin configuration and will mount perfectly on printed circuit board. **\$.99 ea.**

ZENERS-DIODES-RECTIFIERS

TYPE	VOLTS	W	PRICE	TYPE	VOLTS	W	PRICE	
1N4752	3.3	400m	4/1.00	1N4003	200	PIV	1 AMP	12/1.00
1N4751A	5.1	400m	4/1.00	1N4004	400	PIV	1 AMP	12/1.00
1N4752	5.6	400m	4/1.00	1N3650	50	2000M	1.00	12/1.00
1N4753	6.2	400m	4/1.00	1N4148	75	10m	15/1.00	
1N4754	6.8	400m	4/1.00	1N4154	35	10m	12/1.00	
1N4755	15	400m	4/1.00	1N4734	5.6	1w	28	
1N5232	5.6	500m	28	1N4735	6.2	1w	28	
1N5234	6.2	500m	28	1N4736	6.8	1w	28	
1N5235	6.8	500m	28	1N4737	7.5	1w	28	
1N5236	7.5	500m	28	1N4742	12	1w	28	
1N4556	25	40m	6/1.00	1N4744	15	1w	28	
1N4658	150	7m	6/1.00	1N1183	50	PIV	35 AMP	1.60
1N4659	160	10m	5/1.00	1N1184	60	PIV	35 AMP	1.70
1N4901	50	PIV	12/1.00	1N1185	200	PIV	35 AMP	1.80
1N4902	100	PIV	12/1.00	1N1188	400	PIV	35 AMP	3.00

KITS

XR-2206KA SPECIAL \$17.95
Includes monolithic function generator IC, PC board, and assembly instruction manual

XR-2206KB SPECIAL \$27.95
Same as XR 2206KA above and includes external components for PC board

TIMERS

XR-555CP	\$.69	STEREO DECODERS	\$ 3.20
XR-320P	1.55	XR-1310P	3.20
XR-556CP	1.85	XR-1800P	3.20
XR-255CP	3.20		
XR-2240CP	3.25		

WAVEFORM GENERATORS

XR-205	8.40
XR-2206CP	4.85
XR-2207CP	3.49

PHASE LOCKED LOOPS

XR-210	5.20
XR-215	6.60
XR-567CP	1.95
XR-2567CP	2.99

MISCELLANEOUS

XR-2211CP	6.70
XR-2261	3.79

50 PCS. RESISTOR ASSORTMENTS \$1.75 PER ASS'T.

ASS'T. 1	5 ea.	10 OHM	12 OHM	15 OHM	18 OHM	22 OHM												
ASS'T. 2	5 ea.	180 OHM	220 OHM	270 OHM	330 OHM	390 OHM												
ASS'T. 3	5 ea.	470 OHM	560 OHM	680 OHM	820 OHM	1K												
ASS'T. 4	5 ea.	3.3K	3.9K	4.7K	5.6K	6.8K												
ASS'T. 5	5 ea.	8.2K	10K	12K	15K	18K												
ASS'T. 6	5 ea.	22K	27K</															



NEW products

vhf fm transmitter strip and power amplifier



The new T40 fm transmitter strip from Hamtronics, Inc., features crisp, clear, symmetrical modulation, is compatible with carbon or transistorized dynamic microphones and has separate microphone gain and deviation controls for proper modulation setup. It also has sufficient shielded tuned circuits to minimize harmonics and spurs.

The exciter module is designed primarily for two meters; a tripler/driver is available for 450 MHz; other frequencies such as 50, 220 MHz, and the commercial frequencies are available on request. Output power is adjustable up to 200 mW with a power control pot. This level is sufficient to drive the companion power module, and it is also useful as a QRP signal around town or for repeater input. The T40 is also well suited for use as a multi-channel fm signal generator or as a control or supervisory link. The exciter module may also be used on CW for the low ends of the 144 and 432 bands.

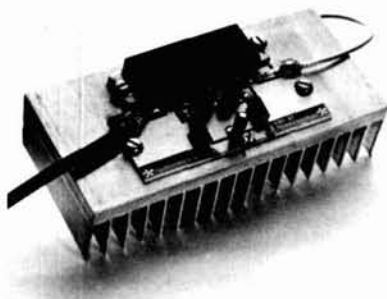
The T40 has eleven channels, with ground-on diode switching suitable for busing with receiver control lines if desired. Sockets are provided for standard, series-resonant 12-MHz HC-25/U crystals, which are readily available.

Separate, multi-turn vernier coils allow individual adjustment of each channel frequency.

The assembled G-10 PC board measures 3x7-1/2x1 inch (7.6x19x2.5cm). It is designed to slide into vertical grooves in the companion cabinet. It may also be standoff mounted in your own package or mounted on the rear of a rack panel. The unit is powered by +13.6 Vdc at 70 mA.

The new T80 rf power modules employ the new "rf modules" recently introduced by TRW and others. These bricks are like magic compared to the tricky and sometimes unstable discrete power amplifiers commonly in use today. The bricks are self-contained, take 200 mW drive and amplify up to a level of 20-25 watts on 2 meters or 13-15 watts on 432-450 MHz. There are no external tuned circuits to fuss with. There isn't any tuning at all! Believe it or not, you simply connect the exciter and antenna to the brick, add 13.6 Vdc, and you're on the air with instant power.

Hamtronics has packaged the bricks with the necessary decoupling components, connection facilities and heatsink and sell the unit all assembled and tested so you have no worry about what you are getting into. Features include vswr protection, no tuning, stability under all normal conditions including vswr, clean output signal, low power drain, and easy installation. The T80 is especially well suited for repeater service since it is unaffected by changes in antenna impedance due to weather.



Input power is 13.6 Vdc at 2-4 amp, depending on drive level and frequency band. Efficiency is 30-50%. Connections for power and rf signals are provided through a PC board which butts up to the leads of the rf power module. Both

are mounted to a heavy heatsink. The heatsink may be attached to the rear panel of the companion cabinet with the power amplifier mounted inside the rear panel, if desired, or it may be mounted to suit your installation. All you need do is attach your coax cables and power lead and you're on the air.

For uhf operation, the T20 uhf tripler/driver module is available to interface between the T40 exciter and the uhf power module. Housed on a PC board, it requires about 200 mW of drive at 2 meters to provide 200 mW output at 432-450 MHz.

Price of the T40 exciter module kit is \$39.95. The T80 rf power module is \$79.95, wired and tested. A companion cabinet is available for \$24.95. The T20 tripler/driver module kit for 450 MHz is \$19.95. For complete information, including an illustrated catalog, send an SASE to Hamtronics, Inc., 182 Belmont Road, Rochester, New York 14612.

instant-weld adhesive



Need a third hand when building equipment? Oneida's new Six-Pak of industrial-strength alpha cyanoacrylate adhesive is available in one-ounce dispensers. Up to 11,400 one-drop applications are possible from this new package of dispensers.

Standard Six Paks come with an assortment of five Instant-Weld formulas; however, you may specify the assortment of your choice. The five formulas are designated by label colors: red, blue, yellow, green, and white. Red label sets the fastest. It bonds many materials in about three seconds, including plastics, rubber, ceramic, or glass.

Thousands of items and materials can be quickly and permanently bonded with Instant-Weld. If you have an unusual bonding problem, write Oneida Electronic Manufacturing, Inc., attention Mr. Dalton Smith, 138 West 7th

NEW FROM MFJ

Street, Erie, Pennsylvania 16501, or call (814) 336-2125. Oneida will make recommendations, which may require a special mix. Instant-Weld is made in the U.S.A. and is guaranteed. The standard Six-Pak sells for \$49.95 postpaid. A brochure is available from Oneida Electronic Manufacturing, Inc., Meadville, Pennsylvania 16335 or use *check-off* on page 102.

QSL bureau for novices

Here's good news for novice amateurs who would like to save money on sending and receiving QSL cards. Jim Isham, W8TX X, operates a novice QSL bureau that works like this: For only \$2.00 per year, a novice may send him as many QSL cards as he wishes, and Jim will re-mail them. All novice amateurs are asked to keep a self-addressed stamped envelope on file with W8TX X to expedite the remailing system.

When a novice subscribes to Jim's service, Jim will send the novice a card with a code number, which must be included in all future mailings. The code is different for each subscriber. At the end of the year's subscription, the novice subscriber will be sent another card, which tells him the year is up and asks if he wishes to subscribe to the service for another year.

Considering the present postal rates for sending cards individually this service looks good indeed. If postal rates increase, savings will be even more. Write to Jim Isham, W8TX X for further details. His address is Box 1111, Benton, Harbor, Michigan 49022.

lowpass TVI filter



Television interference, even from modern transmitting equipment, is still a problem in many areas. A well-designed lowpass filter properly installed in an amateur transmitter can prevent or substantially reduce television

STATE-OF-THE-ART RECEIVER PRESELECTOR



The new MFJ 1030 BX receiver pre-selector sets a new standard of performance! It dramatically improves weak signal reception, significantly rejects out-of-band signals, and reduces image response. You'll be able to clearly copy weak, unreadable signals. (Increases signal 3 to 5 "S" units). Its strong signal handling ability allows you to reduce your receiver RF gain. This results in reduced receiver cross modulation and overloading in presence of strong signals while still maintaining excellent signal to noise ratio. Since most receivers are entirely adequate below 10 MHz, the pre-selector is optimized to cover the 10 to 30 MHz region. Simply connect between antenna and receiver or between transmit-receive relay and receiver input of any transceiver. A 9 volt transistor battery provides months of operation.

Look at these special features from MFJ

- Uses protected dual gate MOSFET for ultra low noise, high useful gain and strong signal handling ability.
- Gain is 20 dB minimum, typically 25 dB.
- Noise figure is less than 2.5 dB.
- Two high Q double tuned circuits.
- A unique feature: separate input and output tuning controls provide maximum gain and selectivity by eliminating the inherent tracking problem of a dual gang capacitor. More expensive, but worth it.
- Completely stable.
- Pre-selector is bypassed in off position.
- Housed in attractive Ten Tec box, eggshell white with wood grain end panels, 2-1/8" x 3-5/8" x 5-9/16".
- Unconditionally guaranteed for one year.

MFJ-1030 BX **\$49.95**

Please add \$2.00 for shipping and handling.

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SUPER LOGARITHMIC SPEECH PROCESSOR



MODEL LSP-520BX

UP TO 400% MORE RF POWER is yours with this plug-in unit. Simply plug 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.



MODEL LSP-520BXII

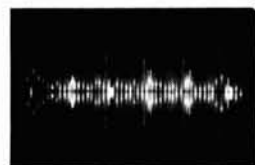


Fig. 2 SSB signal after processing with LSP-520BX. The once weak valleys are now strong peaks. Our NCX-3 now puts out 100 watts of average power.

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 30dB for clean audio with minimum distortion.

This unit is practically distortion-free even at 30dB compression! The input to the LSP-520BX is completely filtered and shielded for RF protection.

Size is a mere 2 3/16H x 3 1/2W x 4D. Money back if not delighted and **ONE YEAR UNCONDITIONAL GUARANTEE**. Order now or write for FREE brochure.

LSP-520BX **\$49.95**

LSP-520BXII **\$59.95**

This unit includes all the features outlined above and then some. A Rotary function switch, an alternate 4 pin mic jack, and a beautiful 2-1/8" x 3-5/8" x 5-9/16" Ten-Tec enclosure are the bonuses included in this option. ADD \$2.00 SHIPPING & HANDLING

Here's another product from the beautiful MFJ line: **SSB FILTER**
This filter, packaged very much like the Speech Processor above, allows you to select the optimum audio bandwidth to drastically improve readability.
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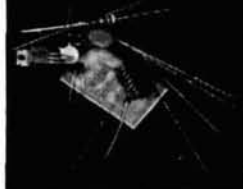
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interference. The R. L. Drake Company has added a new lowpass filter, the TV-3300-LP, to their line of television interference filters. The TV-3300-LP provides more than 80 dB attenuation above 41 MHz and will handle 1 kilowatt maximum input below 30 MHz. More information? Write R. L. Drake Company, 540 Richard Street, Miamisburg, Ohio 45342, or use check-off on page 102.

avionic test-equipment kits



Radio Systems Technology has announced a new line of avionic test equipment. This equipment, designed to give the ham-pilot the capability of bench service of VHF Nav Com transceivers and Marker Beacon receivers, is available for the first time anywhere in kit form. Four separate kits allow the test bench to power 12-volt radios and accurately synthesize navigation and communication signals as well as measure transmitter and audio outputs. All kits may be powered from 110 volts ac, 12 volts dc or internal 9 volt batteries, and are supplied with rod antennas for use as ramp test sets.

The RST-721 Communications Test Set is designed to check all inputs and outputs of vhf communication transceivers for correct operation. This unit is a composite rf and audio wattmeter, voltmeter, ammeter, percentage modulation meter, vswr meter, microphone test set and crystal-controlled 122.8 MHz signal generator. Rf and audio 10-watt dummy loads are built-in. The RST-721 Test Set sells for \$98.50.

The RST-711 Navigation (VOR-LOC) Test Set is designed to test vhf navigation receivers for correct operation. This unit is a crystal-controlled 108.0 and 108.1 MHz signal generator modulated with four major OMNI signals or LOC signals together with pulsed

or continuous IDENT tone. A front panel rf level attenuator allows receiver sensitivity to be checked. The unit sells for \$97.50.

The RST-701 Marker Beacon Test Set is a crystal-controlled 75 MHz signal generator modulated with any of three marker tones, Fan, Outer or Middle Marker. A front panel attenuator selects the desired rf level for checking sensitivity. The RST-701 sells for \$69.50.

The RST-601 is a 12 volt bench regulated power supply which has the capability of simulating battery high limit voltage, nominal, and low limit voltage. Also included on the RST-601 chassis are microphone and headphone jacks, built-in speaker, and three parallel connectors for transceiver interconnection. The unit sells for \$85.00.

The RST-601, 701, 711 and 721 may be purchased as a complete Bench Test Set for \$330.00. For further information, write to Radio Systems Technology, P.O. Box 23233, San Diego, California 92123, or use *check-off* on page 102.

precision frequency comparators

The Dynatron Company has announced two frequency comparators intended for use in calibrating crystal oscillators against television network atomic standards. The comparator generates a vertical rainbow bar on the screen of a color television receiver. The rate of color change of the bar indicates the phase difference between the crystal oscillator output and the network color subcarrier. Frequency calibrations to within a few parts in 10^{10} take just a few minutes.

This calibration scheme, based on techniques and circuits developed by the National Bureau of Standards, is supported by the monthly publication of the network offset frequencies in the NBS Services Bulletin.

The DyCo Model 175 accepts input of 2.5, 5 or 10 MHz while the Model 175-1 accepts 1, 5 or 10 MHz. Price of the Model 175 is \$99.95 while the Model 175-1 sells for \$109.95. For more information contact the Dynatron Company, Post Office Box 48822, Los Angeles, California 90048, or use *check-off* on page 102.

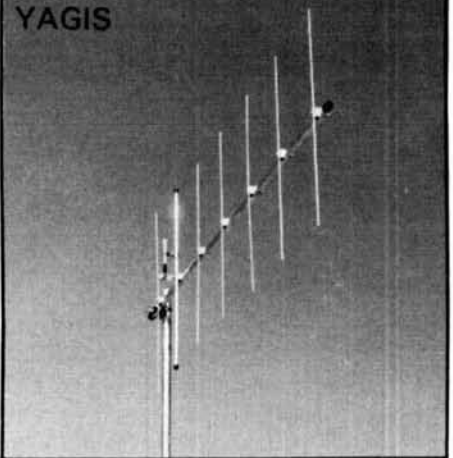
220 FM ANTENNAS by **cushcraft**

YAGIS

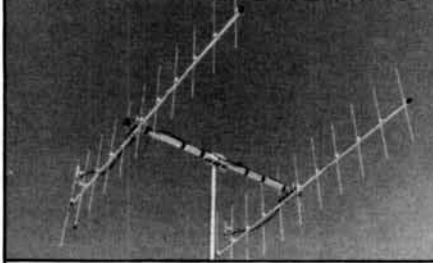
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MODEL A220-11	A220-7
Boom 102"	70"
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A220-VPK complete kit \$19.95
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POWER PACK: 22 element array for 220 FM, with mounting boom, harness and all hardware. Gain 16 dBd F/B ratio 24 dB beam width 42°, dimensions 102" x 50" x 27", weight 12 lbs., 52 ohm feed. A220-22 \$56.50

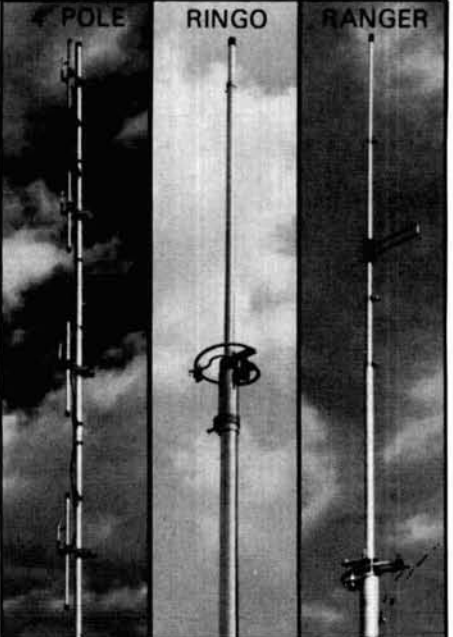
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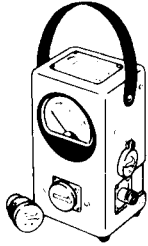
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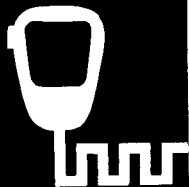
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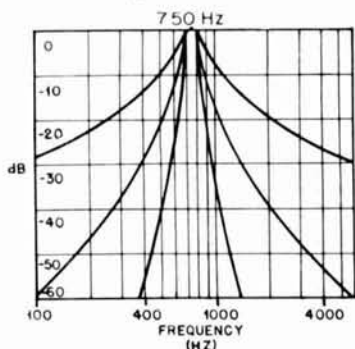
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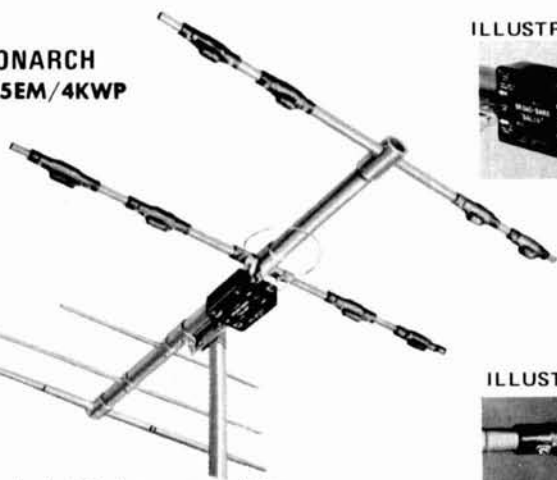


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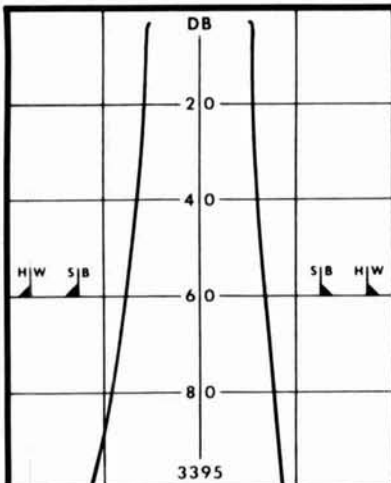
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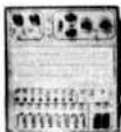


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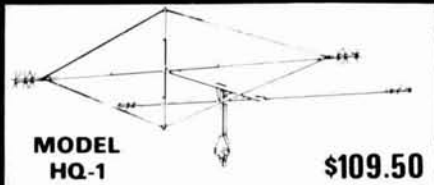
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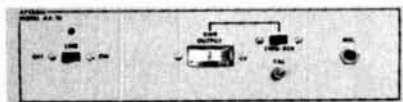


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HAMFESTS Sponsored by non-profit organizations receive one free Flea Market ad (subject to our editing). Repeat insertions of hamfest ads pay the non-commercial rate.

COPY No special layout or arrangements available. Material should be typewritten or clearly printed and must include full name and address. We reserve the right to reject unsuitable copy. Ham Radio can not check each advertiser and thus cannot be held responsible for claims made. Liability for correctness of material limited to corrected ad in next available issue.

DEADLINE 15th of second preceding month.

SEND MATERIAL TO: Flea Market, Ham Radio, Greenville, N. H. 03048.

MUSKEGON AREA AMATEUR RADIO COUNCIL seventh annual hamfest and ARRL Michigan State Convention on Saturday, March 20, 1976 at the Muskegon Community College. Tickets are \$2.25 at the door. The event features: Net Meetings; Technical Forums. Complete in-college dining facilities open all day. Parking free. Friday evening, March 19, at the Muskegon Ramada Inn. Ham hospitality for Eye-Ball QSO'S and free libation. A Wouf Hong initiation midnight Friday at the Ramada for ARRL members. Further information from Hank Riekels WA8GVK, Box 691 Muskegon, Michigan 49443 or 616-722-1378.

PAYING 5% OVER BEST OFFER for Eimac/Varian tubes, ham and commercial gear, etc. Ted Dames, W2KUW, 308 Hickory St., Arlington, N. J. 07032. (201) 998-4246.

NEW JERSEY KNIGHT RAIDERS VHF Club's auction and flea market Saturday, March 20th, St. Joseph's Church of East Rutherford, Hoboken Street, East Rutherford. Free admission, free parking, refreshments available. Talk-in on 146.52 and 146.94. Doors open 11 AM. Flea Market tables: \$5.00/full table, \$3.00/half table. Reserve tables in advance by writing Knight Raiders VHF Club, K2DEL, P.O. Box 1054, Passaic, New Jersey 07055.

MANUALS for most ham gear made 1940/65, some earlier. Send SASE for specific quote. Hobby Industry, W0JJK, Box H-864, Council Bluffs, Iowa 51501.

ARRL HANDBOOKS WANTED. 1st, 5th, 6th and 8th editions to complete my collection. Highest prices paid for copies in good condition. Also need 13th and 14th editions of the RADIO Handbook. Have many early Handbooks and electronics/radio books for sale or trade. Send SASE for list. Jim Fisk, W1D7Y, Ham Radio, Greenville, NH 03048.

STOP don't junk that television set. ASE manufactures the world's most complete line of television picture tubes. Over 1700 types. Most types immediate delivery. Tubes for Old or New TV's, black & white and color. 2 year factory warranty. Lowest prices anywhere. Allied Sales & Engineering, Inc., Dept. 22, Pimento, IN 47866. Telephone 812-495-6555.

R/9 AND RADIO MAGAZINES needed to complete my library. Some duplicates available for trade with other collectors. Also have many early radio publications and Handbooks for sale or trade. Send SASE for list. Jim Fisk, W1D7Y, Ham Radio, Greenville, NH 03048.

SB-104 OWNERS CLUB — Expanding its horizons to include the HW-104 and the new Heath 2 meter equipments. Newsletter, builders guides, modification information and other services on current Heathkit amateur equipments. Send SASE for details to Chuck Harrison, RD 2 Box 1, North Stonington, CT 06359.

HAM RADIO BACK ISSUES AVAILABLE. March 1968 (first issue), all issues from 1969, 1970, 1971. January through August and November and December 1972, January, February, March, 1973. Write Ronald L. Wood, 620 - 113th Ave. S.E., Waseca, MN 56093.

VERY in-ter-est-ing! Next 4 big issues \$1. "The Ham Trader," Sycamore, IL 60178.

KLM PRODUCTS, Larsen ants., lcom, police and fire scanners. Send for prices. Not given over phone. Narwid Electronics, 61 Bellot Road, Ringwood, N. J. 07456.

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

LEARN CODE IN A FEW DAYS with audio reflex method of teaching letters, numbers, punctuation. One hour cassette only \$7.00. Guardian, 20 E. Main St., Ramsey, N. J. 07446.

STOLEN 2M FM transceiver from my car on December 9, 1975 in Cleveland, Ohio. IC-230, serial #2403009. Rig was taken without mike. Contact Ferd H. Nye, Jr., W8BNXT, 31497 Hilliard Blvd., Westlake, OH 44145.

NOVICE, GENERAL AND CODE COURSES are available at the Harrison, New York School of Continuing Education. 10 two hour sessions one evening a week. Contact George Buchanan WB2FVX, (914) RO-1-4183.

REGENCY TMR-1H RECEIVER CASE comes complete with transformer, speaker, front panel controls, power plug, and mobile mounting bracket. Makes a great case for any mobile ham project! 12.95 2/25.00. Avel Electronics P.O. Box 4072 Rochester, New York 14610.

MICROPROCESSORS AT DAYTON. Don't miss Ham Radio's exciting one day Microprocessor Seminars to be held on both Friday, April 23 and Saturday, April 24. Taught by professionals. Widely acclaimed as one of the outstanding parts of this year's SAROC. Full details in display ad in this issue or from Ham Radio, Greenville, NH 03048. 603-878-1441.

WANTED 33 ASR TELETYPE Must work perfectly. Price, condition, serial number. Brian WA4REF (803) 846-2519. 348 Ash, Laurel Bay, SC 29902.

THE 21ST ANNUAL HAM AUCTION. America's Largest. Saturday, March 13, 1976, at Lucas County Recreation Center, Toledo, Ohio. Auction, flea market, commercial displays, prizes. 8:00 a.m. to 5:00 p.m. \$1.50 advance, \$2.00 after March 1st. Send SASE. Talk-in 146.52. Toledo Mobile Radio Association, Box 273, Toledo, Ohio 43696.

SELL: IC-30, six channels crystals installed, \$300. IC-22, \$175.400B channelizer cabled for IC-22, \$175. Hy-gain 18AVT/WB-A new, \$50. Slinky antenna, \$20. All excellent condition. 1732 Willow Point, Shreveport, La. 71109.

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

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RARS 1976 ANNUAL HAMFEST, April 11. For details write: RARS, Box 17124, Raleigh, N. C. 27609.

AUCTION: Saturday, March 20, 9 to 5 at the DAV Bldg. Arena Drive, Trenton, New Jersey. Take Exit 7-A off New Jersey Turnpike then I-195 to Trenton Exit 2, Arena Drive, then 1.6 miles on Arena Drive. Talk-in on 84.24 and 52. For more info call Carl 609-599-1868. No admission charge. 10% fee, 3% buy back and \$1.00 minimum. Proceeds to benefit Lawrenceville Repeater Group.

TELEVISION diagnostic repair course prepared by master technicians. Lessons only \$6.00 each. Optional matching one hour cassette tape \$6.00 each. Send for first lesson and master index. Guardian, 20 E. Main, Ramsey, N. J. 07446.

TREASURE COAST BI-CENTENNIAL HAMFEST Sat.-Sun. March 20-21, 1976. The "Biggest Little Hamfest In America". For info write: K4QM, P.O. Box 3088, Vero Beach, Fla. 32960.

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

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flea market

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WANTED: Manual for Philco visual alignment generator model 7008. Will buy, copy and return or pay for copying. Also want Heath monitor scope HO-10 and Ham scan. John Dillon, KH6FMT, Box 758, Koloa, HI 96756.

ROCHESTER HAMFEST 1976 is Saturday, May 22. Your name added to mailing list or information — write: Rochester Hamfest, Box 1388, Rochester, N. Y. 14603.

COLLINS R-390A \$500. 51S-1 military version edge lit front panel \$800. Both mint condition and just aligned. David Ross Box 1502, San Luis Obispo, CA, 93406, 805-541-0794.

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.

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KENTUCKY HAM-O-RAMA — Sunday, May 30 (Memorial Day Weekend) at Boone County Fairgrounds, Burlington, Kentucky. 10 minutes south of Cincinnati, Ohio near I-75. Prizes forums, XYL program, exhibits, flea market. Tickets \$1.50 advance. Info: NKARC, P.O. Box 31, Fort Mitchell, Kentucky 41017.

PC BOARD negatives made photographically from your or magazine's art work. 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.

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WANTED: Would like to contact "Homebrewer" in San Francisco Bay area. Exchange ideas etc. Wayne Hale, WA6LCW 839 Mendocino Ave., Berkeley, CA 94707. 525-5702.

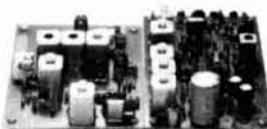
UNSCRAMBLE POLICE CODE with decoders. Works on all scanners and receivers. Guaranteed. For prices and brochure write: Don Nobles, Rt. 7, Box 265B, Hot Springs, Ark. 71901. 501-623-6027 (Dealer inquiries invited).

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flea market

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GREATER BALTIMORE HAMBOREE, Sunday, April 4th at 9:00 a.m. at Calvert Hall College, Goucher Blvd. and LaSalle Road, Towson, Maryland 21204. (1 mile south of Exit 28 Beltway - Interstate 695) Prizes, flea market, registration \$2. 250 tables inside gym. Over 1000 attended last year. Info: Contact Brother Gerald Malseed, W3WVC at the above address.

ANTENNAS: Dipole, multiple band arrays. 15 thru 75 meters from \$59.50. Mobile Antennas — CB, 20M, 40M, and 2M from \$19.50. Baluns: 1:1 and 4:1 - \$12.95 ea. Data Available. Savoy Electronics, Inc., P. O. Box 5727, Ft. Lauderdale, Fla. 33310.

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

ROCK RIVER HAMFEST, April 25, Amboy, Illinois. Lee Co. 4-H Center, Jct. 30 & 52. Same place as last year. For further details see hamfest calendar. \$1.00 advance, gate \$2.00. Write Carl Karlson, W9ECF, Nachusa, Illinois

DRAKE TR4 TRANSCEIVER, RV4 remote VFO, and AC3 - \$525. N. Keedy, 175 Beacon St., Boston, MA 02116.

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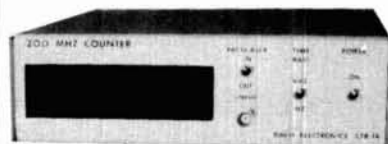
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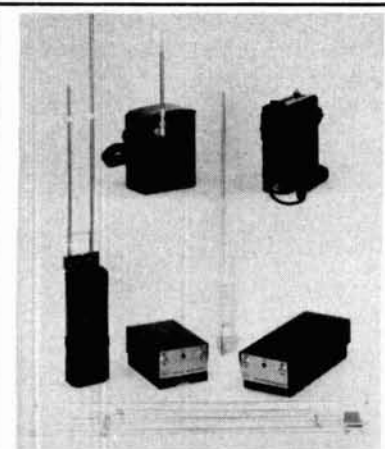
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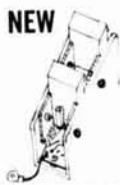
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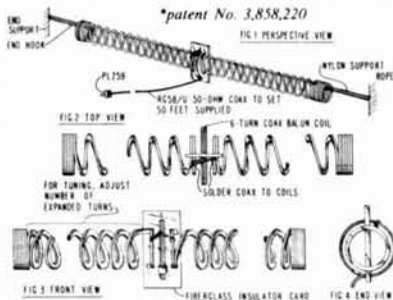
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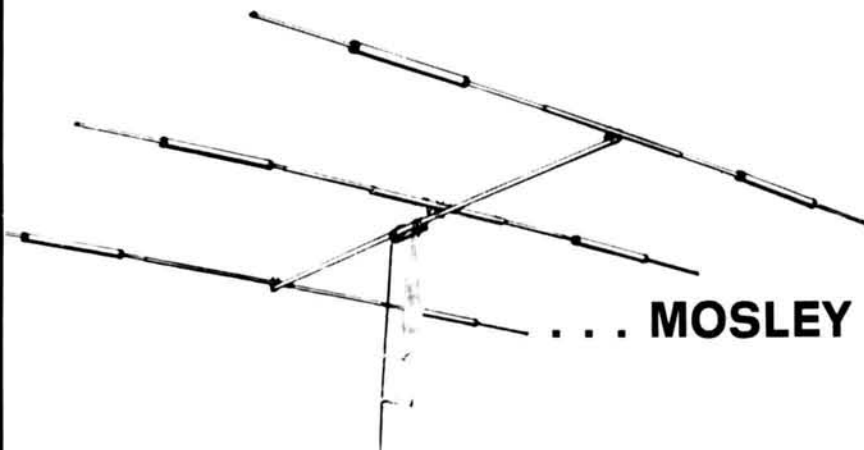
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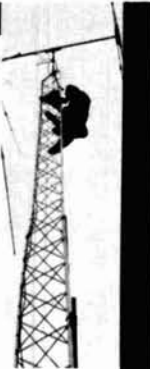
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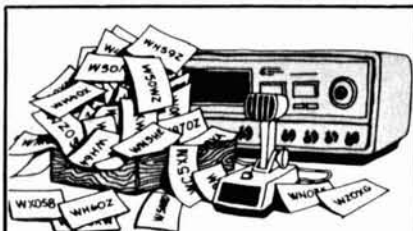
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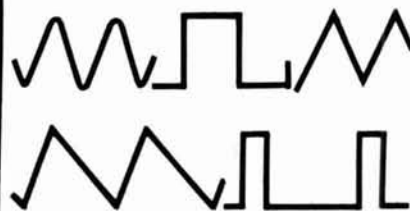


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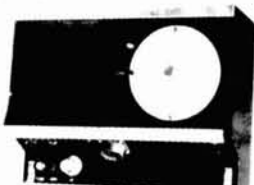
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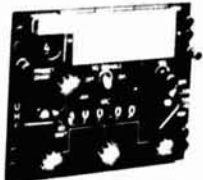


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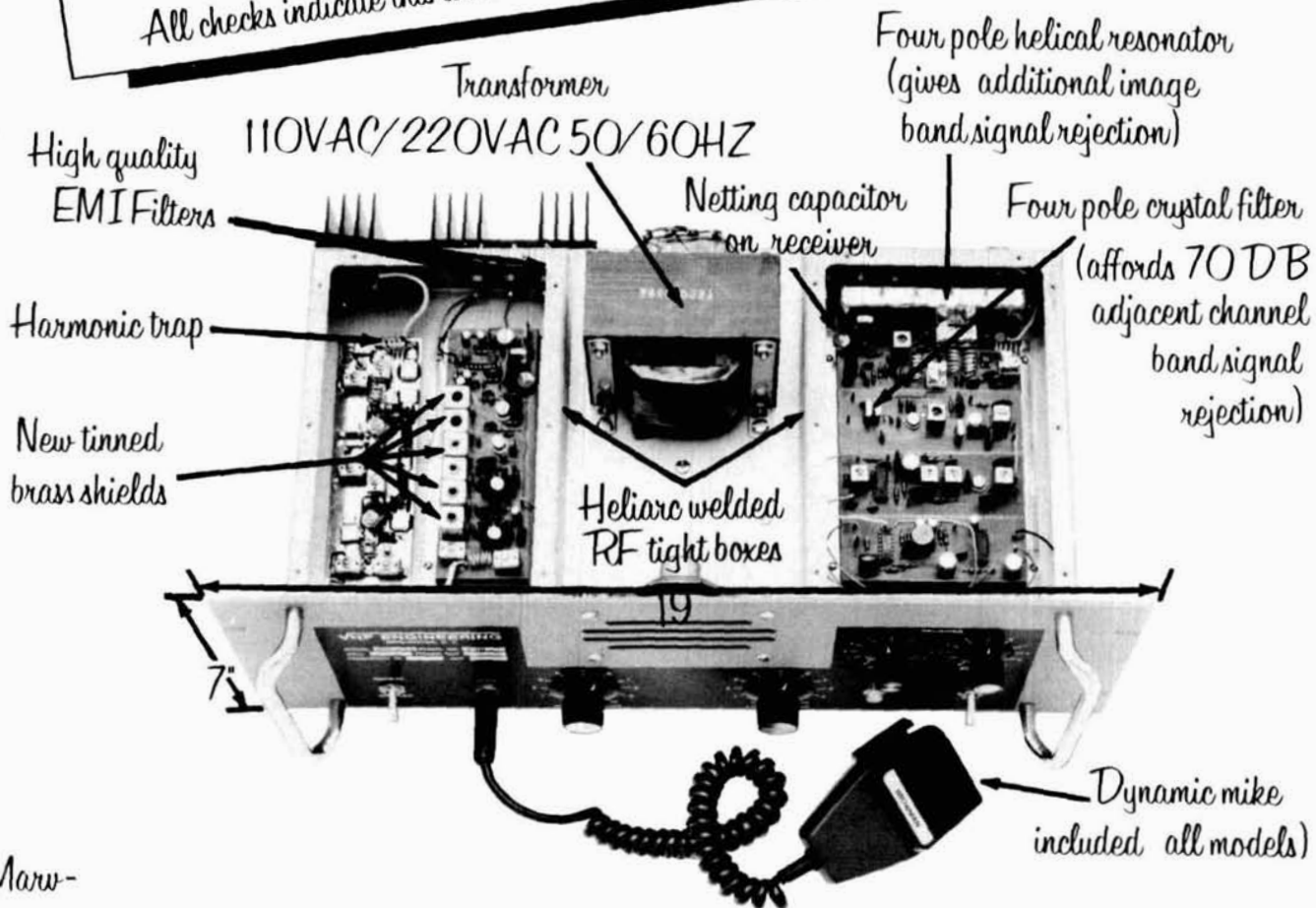
INTER-OFFICE MEMO

TO: MARVIN DRUSKOFF, General Manager
 FROM: ROBERT BROWN, Chief Engineer

DATE 12/1/75

Here is the information on our new "B" series of repeaters.
 All features are standard on all units; kits as well as wired.
 All checks indicate this is the hottest repeater on the market.

Standard features on all
 repeaters
 (Kit or Wired & Tested)
 B series.



Marv-

Not shown in photo is new power supply. Has fold back current limiting (you can short supply & will not damage it), also over voltage protection (a short in the supply will shut it down so repeater is not damaged.) Don't forget our CWID with its 159 bit field programable memory.

Bob

PRICES

RPT 144B Kit . . .	repeater - 2 meter - 15w - complete (less crystals)	465.95	RPT 144B	repeater - 15 watt - 2 meter - factory wired and tested	695.95
RPT 220B Kit . . .	repeater - 220 MHz - 15w - complete (less crystals)	465.95	RPT 220B	repeater - 15 watt - 220 MHz - factory wired and tested	695.95
RPT 432B Kit . . .	repeater - 10 watt - 432 MHz (less crystals)	515.95	RPT 432B	repeater - 10 watt - 432 MHz - factory wired and tested	749.95



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VHF Mobile/Base Station

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Add up all these features and you have another total performance transceiver from **the radio company**.



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Join the VHF action with the FTV-650B and FTV-250. These matching economical additions offer VHF transmitting and receiving when coupled to your HF transceiver.

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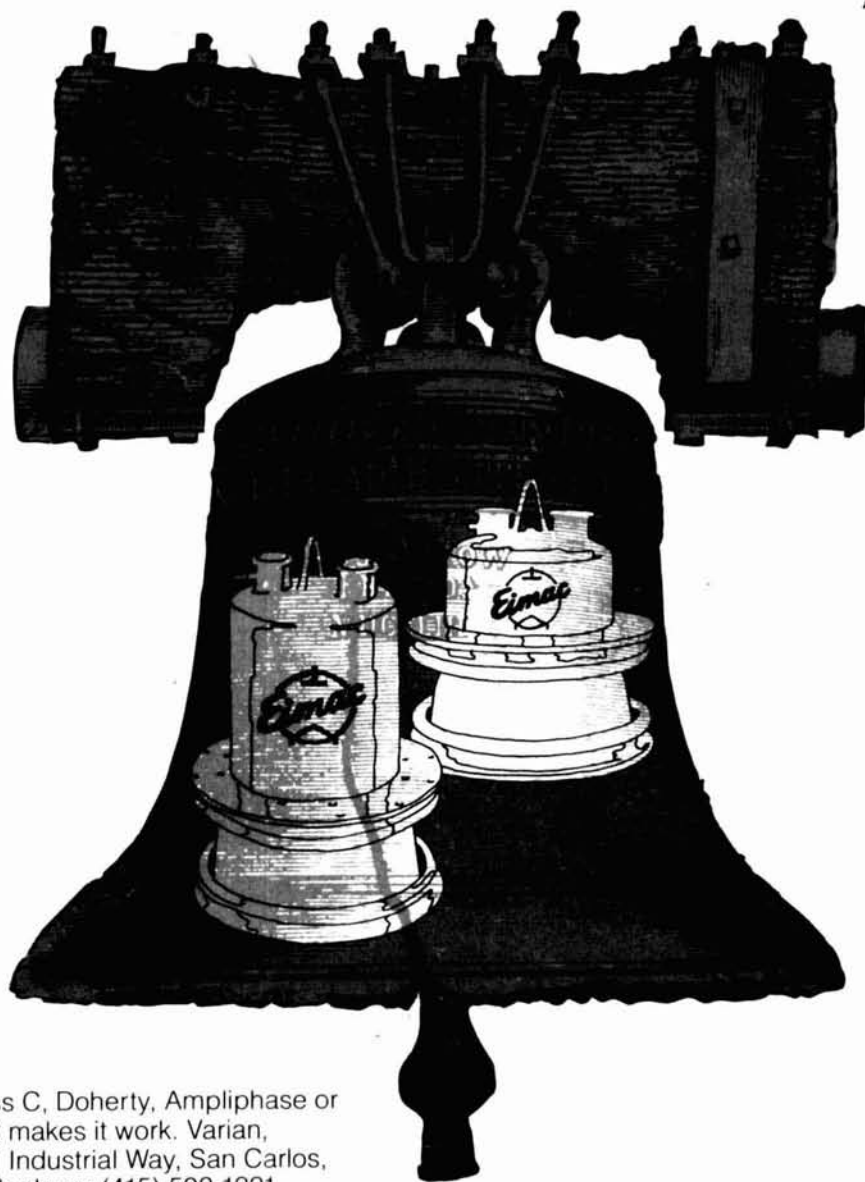
See your Yaesu dealer or write for our catalog. **Yaesu Musen USA, Inc., 7625 E. Rosecrans, No. 29, Paramount, California 90723**

FTV-250
2 Meter Transverter



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to better serve the people
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