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ham radio magazine

OCTOBER 1974

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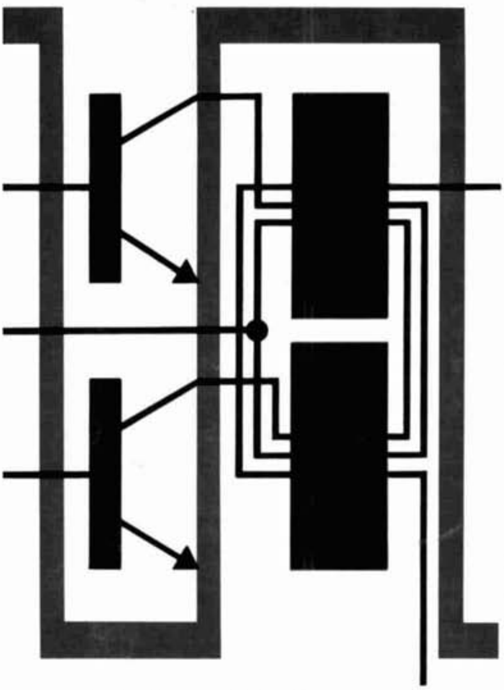

high-efficiency rf power amplifiers

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a second look

by jim fisk

In our ever more populated world, with its growing proliferation of electronic gadgets, it's the rare amateur who hasn't been bothered at one time or another by interference complaints. In the 1930s, as more and more broadcast stations came on the air, it was BCI. Then, in the late 1940s, it was TVI. Now, with exotic solid-state stereo and quadraphonic systems, the interference problem has become more widespread. It's also much more difficult to cure. Nor, as I pointed out in this column over a year ago, is the problem limited to amateurs. Consumers who live near high-powered television and fm broadcast stations regularly complain of unwanted interference. And the 900,000 or so class-D CB stations receive a share of the blame as well.

Clearly, the problem can be effectively solved only by proper design and construction at the manufacturing level. Why, you may ask, isn't this done now? Wouldn't it be a lot easier to properly design the equipment in the first place than to try to cure the problem piecemeal after the equipment is installed in the consumer's home?

The answer lies in the economics of the design and sale of equipment in a highly competitive market. The manufacturers are obviously reluctant to add filtering or lead bypassing that would increase the size of the price tag. Until recently, in fact, they have contended that only 1% of home entertainment equipment operates in a strong rf environment which requires additional lead filtering or bypassing. However, an Electronics Industries Association spokesman acknowledged recently that the widespread growth of two-way radio systems, as well as higher-power a-m and fm broadcasting stations warrants another look at the manufacturers' present position. However, with dwindling profit margins brought on by inflation, I see little chance manufacturers will voluntarily do anything to solve the RFI problem.

What is needed is Congressional or FCC action to require all manufacturers of TV sets, stereo systems, and a-m and fm receivers to build interference suppression into their designs. Although the late Rep. Charles Teague of California introduced Congressional legislation in 1973 which would have required radio and television sets to meet FCC standards for filtering out interference, that bill, which is still pending, did nothing about radio interference to audio equipment. And, according to Rep. Torbert Macdonald of Massachusetts, Chairman of the House Commerce Subcommittee on Power and Communications, there is considerable legislative opinion that the FCC can require the manufacturers to put lowpass filters into TV receivers without additional legislation.

The ARRL Radio Frequency Interference Task Group, which has been working on the problem for over a year, has put together a packet of material which may prove helpful if you are experiencing rf interference problems. The packet, which includes a wealth of useful data, is available by sending a large (9x12-inch), self-addressed Manila envelope with $0.40 postage to Ted Cohen, W4UMF, 8603 Conover Place, Alexandria, Virginia 22308. Included is a questionnaire which will assist the ARRL RFI Task Force in its work with the FCC and representatives of the electronics industry. Let's all get behind this worthwhile effort.

Jim Fisk, W1DTY
editor-in-chief

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presstop

AMATEUR RESPONSE TO CURRENT FCC DOCKETS DISAPPOINTING as few amateurs take time to comment on the many important FCC actions now pending. Let's get with it!

Three Long-Awaited Repeater Actions (repeater linking, cross-banding and automatic control) have received a grand total of two comments thus far, both on automatic control (one wants rules tightened, other wants no rules at all!).

RACES Docket, on the other hand, has had lots of response -- 95% of it from RACES people, and almost 100% of that "anti-ham!" Comments range from "RACES needs paid professional operators -- hams are not competent emergency communicators" to one state organization that proposes taking the present RACES band segment away from the amateur service and reassigning it to state and local governments for full-time RACES use! One thing is certain: RACES has not received good amateur support in most areas.

REDUCED FEES FOR AMATEUR LICENSES offered in Docket 19658 issued August 12. License modification without renewal would be reduced to $5, renewal or new licenses to $6. Special calls remain at $25. Comments by September 20, replies by October 4.

SHARED INDUSTRIAL USE OF 420-450 BAND PROPOSED in FCC Docket 20147, adopted August 21. Docket would permit operation of HIRAN, a high-accuracy radio-location system developed for precise location of offshore oil-drilling rigs. System would use frequencies within the amateur/government-radio-location band on a non-interfering temporary basis through January 1, 1978. Comments are due by November 4.

ARRL ADVISORY COMMITTEE OPENINGS on the Contest, DX and VHF Repeater committees upcoming as many present appointments expire January 1, 1975. Nominations to fill the open slots are solicited, and the proper forms for making nominations are available on request from ARRL headquarters in Newington, Connecticut.

HAWAII SITE FOR NEW 1975 HAMFEST. Promoted by Leonard Norman of SAROC/Las Vegas fame, this new show is in addition to SAROC. A week-long affair is planned with package deals from all major U.S. cities. For developing details write to Leonard at SAROC, Box 945, Boulder City, Nevada 89005.

NATIONAL RADIO RIDES AGAIN. All assets of the former National Radio Company have been purchased by new National Radio Company, Inc., with plans to resume manufacture of most of the former company's product lines in Melrose, Mass.

PROBLEM WITH KEYBOARD CW BUFFS is proper IDing. FCC monitors are not set up to copy super-high-speed CW, so perhaps FCC rule limiting RTTY CW ID to 20 wpm should be extended to all modes. Forearmed is forewarned...

FCC COULD LICENSE ALIENS under provisions of Senate bill S.2457 now under consideration. This bill would enable many now prohibited to become licensed, and expedite licensing of others now eligible by bypassing considerable red tape.

ILLINOIS STATE POLICE APPLY FOR 2000 CB LICENSES, put FCC on spot as to whether this is "proper" CB use. Police/citizen groups are using CB in several areas, but question seems to be what impact CB licensing of a large force would have.

AT TEXAS VHF-FM SOCIETY CONVENTION in August FCC Amateur and CB Division Chief Prose Walker delivered a Special Temporary Authority for activation of TIRS (Texas Intercity Relay System) that permitted demonstration of the capabilities of this sophisticated multi-repeater linkup.

Prose also discussed restructuring of amateur radio, and reviewed a variety of possible approaches including a separate license for HF or VHF/UHF (with distinctive prefix -- AA-AL block is already ours, and attempts are being made to break N and NA-NZ prefixes loose from the Navy).

ARRL NEW ENGLAND DIVISION DIRECTOR CHAPMAN RETIRES effective December 31, but Bob, W1QV, plans to continue as President of the ARRL Foundation until the end of his term next March.

high-efficiency rf power amplifiers

Design and construction of solid-state rf power amplifiers that offer operating efficiencies of 90 percent or more

Frederick H. Raab, WB8LQK, 11762 Cedarcreek Drive, Cincinnati, Ohio 45240

Since the demise of the spark gap, radio amateurs have been plagued by inefficient transmitters. The transistor eliminated the power consumed by the filaments of vacuum tubes, but the inefficiency inherent in class-A, -B and -C amplifiers remained. Now class-D techniques (also called switched-mode or class-S) offer a means of eliminating some of the remaining inefficiency. These techniques can be applied to both audio and rf amplifiers, as well as to voltage regulators.

There are a lot of reasons an amateur might want to use class-D, including less input power for the same output, more output for the same input, smaller power supplies or batteries (lower energy consumption), and smaller heatsinks and transistors. In addition, the transistors don't have to be linear.

You might use class-D to build a transmitter with a legal *output* of 900 watts. High-efficiency operation will keep this rig from heating your operating room at the same time. Class-D operation not only reduces your electric bill, it result in saving even more power at the generat ing plant (1 to 2 watts there for each wat saved in your transmitter).

Why are ordinary amplifiers ineffi cient, anyway? When used as a class-A, -E or -C amplifier, a transistor (or tube, fet etc.) sustains a non-zero voltage while it is conducting current. Whenever both volt age and current are present, power is consumed. The amount of power con sumed depends on the class of operation — what portion of the time the active device is actually conducting cur rent.

Class-A amplifiers conduct current al the time, and when amplifying a sine wave, efficiency is no greater than 50 percent. Since class-B amplifiers conduct current half the time, they can achieve 78.5% efficiency with sine-wave signals. Class-C amplifiers conduct current less than half of the time and do not, theoretically, have limited efficiency. However, practical limits (drive power, peak current, etc.) make it difficult to achieve very high efficiencies; maximum typical efficiency for class-C operation is 85 percent.

Class-D operation can provide more efficiency because it avoids the conditions of simultaneous non-zero voltage and non-zero current which cause power to be consumed in the transistor. The transistors act as switches. When the transistors are *off* (open), the current is zero, so no power can be dissipated. When the transistors are *on* (closed), the transistors have (nearly) zero voltage drop across them, so again no power is dissipated. So long as the transistors can be switched

Author Raab, who was previously licensed as WAØATT, is employed by the Cincinnati Electronics Corporation in Cincinnati, Ohio, manufacturers of electronics equipment for the government.

fast enough and saturated well enough, high-efficiency operation is possible.

The difference between linear and switched-mode amplifiers is best shown by an example. Suppose that you have a lamp which consumes 100 watts when connected to 100-volts dc, and that you want to dim it to 50 watts (**fig. 1**). The easiest way to reduce power is to insert a resistor in series with the lamp, adjusting its value to produce 50-watts dissipation in the lamp. If you go through the calculations, you will find that this *class-A* dimmer consumes about 20.7 watts, making its efficiency 70.7 percent.

To make a class-D dimmer, you would use a switching transistor instead of the resistor (**fig. 1C**). The transistor would be driven so that it is turned on 50% of the time and off the other 50%. The lamp will then consume an average of 50 watts and the transistor switch will consume (almost) nothing, thus having an efficiency of (almost) 100%. Note that the switch must

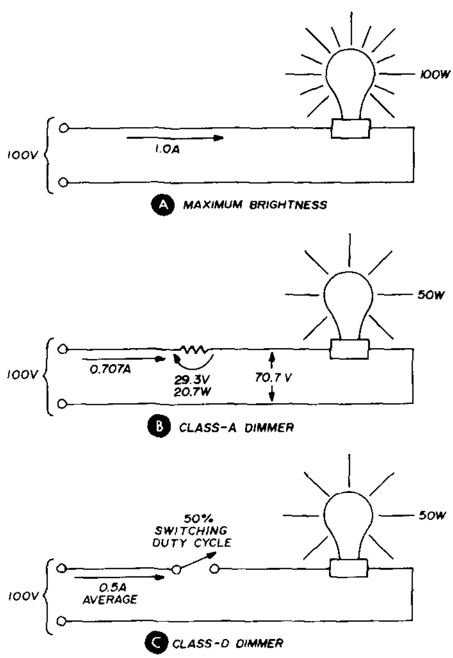


fig. 1. Simple class-A and class-D light dimmers illustrate relative efficiency of the two classes of operation. In the class-A light dimmer (B), maximum efficiency is 70.7%. Efficiency is nearly 100% in the class-D dimmer (C).

operate fast enough so that you cannot see the lamp flicker.

A technique which is useful when designing linear high-efficiency rf amplifiers is *envelope elimination* and *restoration*. The EER technique (**fig. 2**) was developed by Kahn in the early 1950s as a means of adapting high-power a-m transmitters to ssb service.[1,2] Basically, this technique treats a single-sideband signal as a carrier which is both amplitude and phase modulated. Before amplification, the envelope (amplitude) is detected and the carrier amplitude is limited. The phase-modulated, constant-amplitude carrier may now be amplified by nonlinear rf amplifiers. The envelope signal is an audio signal with frequency components from dc to about 10 kHz (four times the tone separation will do), and can be amplified by linear audio amplifiers. The two signals are combined by amplitude modulating the last stage of the rf amplifiers, producing an amplified ssb signal. This technique is useful in high efficiency amplification since it is generally much easier to build linear class-D audio amplifiers than linear class-D rf amplifiers.

In this article I will attempt to give you a basic understanding of what class-D operation is all about. Understanding class-D requires close attention to where current flows and why a voltage is what it is. Never assume a particular waveshape just because it seems reasonable; make sure something causes it.

class-D audio amplifiers

Class-D audio amplification is often referred to as *pulse-width modulation* (PWM) because this technique is used in class-D audio amplifiers. Applications include both amplitude modulators and loudspeaker amplifiers, and all power levels of interest to amateurs are feasible. The use of integrated circuits makes the modulation circuitry quite simple.

Audio-frequency PWM is somewhat similar to the class-D light dimmer. A combination of transistors and diodes acts as a switch which applies a voltage pulse train to the load through a lowpass filter. The pulse width determines the average voltage, which is the output of the lowpass filter. The output (average) voltage can be varied to reproduce a desired audio signal by varying the pulse width.

a-m modulator

When a class-D audio amplifier is used rent flow and draws what it needs through the diode. Therefore, the diode acts as part of the switch and cannot be eliminated from the circuit. Note that no current at the switching frequency flows into the load; hence, there is no power dissipated at the switching frequency. When the transistor or diode conducts current, the voltage across it is very small

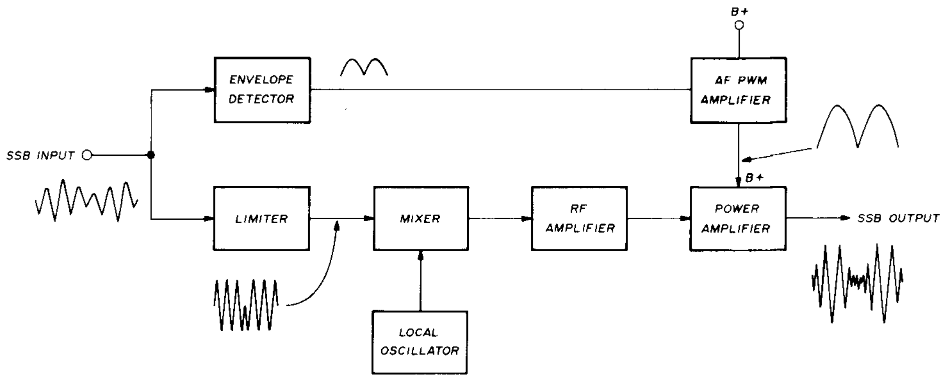


fig. 2. Block diagram of the basic envelope elimination and restoration system. This technique permits the use of non-linear rf power amplifiers in ssb service.

as an a-m collector modulator, both the voltage and current outputs will always be positive. The switch, composed of a transistor and a diode (**fig. 3A**), connects the inductor in the lowpass filter to either $+V_{cc}$ or ground (zero voltage). The lowpass filter has a high input impedance at the switching frequency, but allows the desired audio frequencies to reach the load. Load resistor R represents the rf amplifier to be modulated.

If the pulse width is 50% of the period of the switching frequency, the average voltage is 50% of V_{cc}. Since the lowpass filter allows only low-frequency voltages to reach the load, with a 50% pulse width a current of $V_{cc}/2R$ flows in the load. As the pulse width is varied from zero to 100%, the load voltage varies from zero to V_{cc}, and the load current varies from zero to V_{cc}/R.

When the transistor is driven *on*, current flows through the inductor into the load; when the transistor is turned *off* it stops conducting current. The inductor resists any instantaneous change in current (saturation voltage), so the switch is very efficient.[3,4,5]

loudspeaker amplifier

If class-D is to be used in an audio power amplifier or other ac-coupled application, the output circuit becomes more complicated as shown in **fig. 4**. A blocking capacitor, C_B, prevents dc current from flowing into the load but requires that current be able to flow from the load into the switch during any part of the ac cycle. This requires a second transistor-diode pair. A pulse width of 50% produces no current flow at all. As the pulse width is varied, low-frequency current flows into the load.

A third variation of the output stage is sometimes called the class-BD amplifier[6] (the previous configurations are then called class-AD). The class-BD circuit is essentially both a positive and a negative voltage modulator (**fig. 5**). This configuration is very versatile because it can produce both ac and dc outputs. Also, when there is no signal input, the ampli-

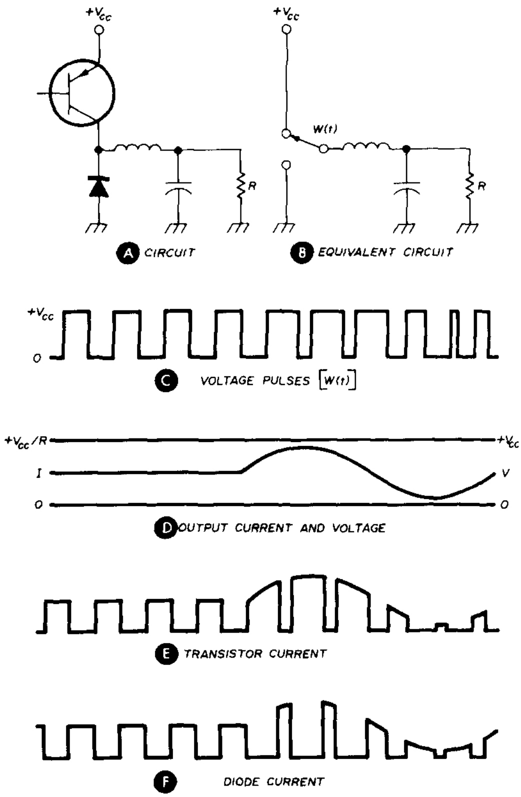


fig. 3. Basic audio-frequency pulse-width modulation circuit with voltage and current waveforms.

fier can simply shut down and conserve drive power. However, the driving and modulation circuitry is proportionately more complex, and two power supplies are required. Diodes CR1 and CR2 prevent conduction by the collector-base junctions of transistors Q1 and Q2 when Q3 and Q4 are turned *on*.

circuit parameters

In class-D audio power amplifiers the switching frequency must be somewhat higher than the highest audio frequency desired so the lowpass filter can eliminate switching frequency energy from the output. A ratio of 10:1 is nice, but a ratio of 5:1 (sometimes a little less) will do. In no case can the switching frequency be less than twice the highest audio frequency.

A pulse train contains a dc component, the switching frequency and its harmonics. As the pulse width is modulated, the dc component is modulated linearly to produce the desired output signal. The switching frequency and its harmonics are also modulated, but their modulation is highly nonlinear, resulting in a large amount of splatter near these frequencies. When the switching frequency is much higher than the audio frequency the splatter is reduced to negligible levels at the passband of the output filter.

The input impedance of the low-pass filter should be much higher than the load resistance to prevent significant current flow at the switching frequency. A good way to accomplish this is to use a large inductor at the input of the filter — its reactance, at the switching frequency, should be ten times the load resistance.

If the class-D amplifier is used as a loudspeaker amplifier, the output filter should attenuate the switching frequency by at least 40 dB. If the circuit is used as an a-m modulator, the filter should attenuate the switching frequency 80 dB to prevent adjacent-channel interference. A two-pole, lowpass filter will provide 40-dB attenuation per decade; a four-pole filter will provide 80-dB per decade attenuation.

It is convenient to make the cutoff frequency of the filter equal to the highest audio frequency and the switching frequency ten times higher; this allows 40-dB attenuation of the switching frequency for each two poles (L-C pair) in the output filter. The inductor value is chosen to have a reactance of 10R at the switching frequency and the capacitor is chosen to resonate with the inductor at the cutoff frequency. The capacitor can be any good quality capacitor. The inductor should use a toroid which has relatively high Q at the switching frequency.

generating PWM

Pulse-width modulation can be accomplished quite easily using only a couple of integrated circuits. **Fig. 6** shows how a triangle wave can be compared to the audio input signal to generate pulses *with* widths proportional to the audio input. Whenever the input audio signal is greater than the triangle signal, the output pulse amplifier is driven *on*.

A good triangle wave of about 1-volt peak-to-peak can be generated by integrating a 12-volt peak-to-peak square wave with a lowpass R-C filter. The square wave can be generated by a simple multivibrator built from cmos NOR gates as shown in **fig. 7**. A high-speed comparator such as the 710 is then used to produce the pulses (**fig. 8**).

An alternative means of generating the pulses is to use a NE555 timer IC. The circuits are described in the applications notes.[7] This modulator varies only the trailing edge of the pulse, but that really doesn't matter much. For linear PWM, however, you must charge the modulator capacitor from a current source rather than through a resistor. A recent paper by Subbarao[8] describes a simple PWM circuit using a unijunction transistor to generate the triangle wave (if you try his circuit, I suggest using the diodes in the output as described here).

pulse amplifiers

Switching (pulse) amplifiers can be designed quite easily since there are only three basic considerations:[9]

1. There must be enough base current to saturate the transistors.

2. There must be enough drive voltage to cut off the transistors.

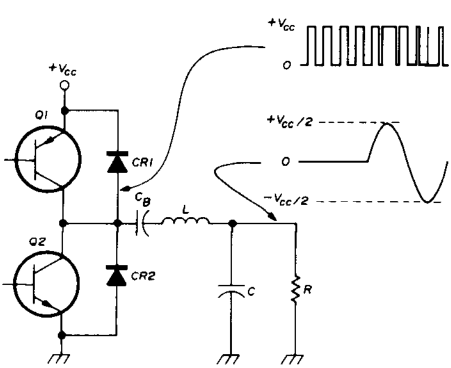


fig. 4. Basic class-D audio power amplifier (also called class AD).

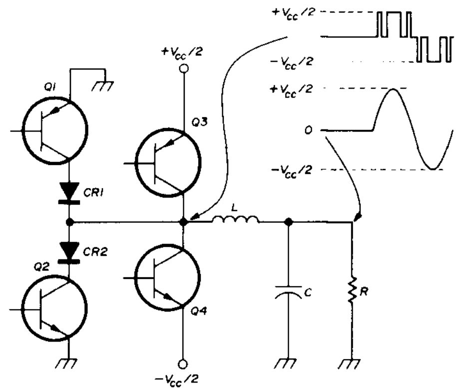


fig. 5. This class-D amplifier (also called class BD) can produce both ac and dc outputs.

3. Rise time must be much smaller than the switching frequency.

The third requirement is satisfied by using transistors with a gain-bandwidth product at least ten times the switching frequency (or transistors with a rise time no larger than 5% of the switching period). There are many inexpensive switching transistors suitable for low and medium power levels.

Pulse amplifiers are best designed by working from the output stage back to the pulse source. A sample design is shown in **fig. 9**. Assume that the peak output current is 1 ampere, and that the minimum current gain of transistor Q3 is 25 (from the data sheet). The base current required to saturate Q3 at all times is then

$$i_{b3} = \frac{i_{c3}}{\beta} = \frac{1A}{25} = 40 \text{ mA}$$

The output transistor is to be driven by the complimentary transistor pair, Q1 and Q2. Under saturated conditions, silicon transistors have typical collector-emitter voltages of 0.3 volt and typical base-emitter voltages of 0.7 volt. Transistor Q2 must be *on* to turn Q3 *on*, so the voltage at point D will be 0.3 volt. The voltage on the base of Q3 (point E) will be 0.7 volt below V_{cc}, or 11.3 volts. The maximum value of R3 is then

$$R3_{max} = \frac{11.3 - 0.3}{0.040} = 275 \text{ ohms}$$

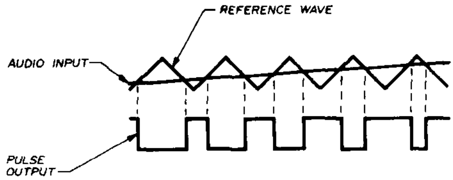


fig. 6. A PWM signal can be generated by comparing a sinusoidal input signal to a reference triangle waveform. A suitable triangle waveform generator is shown in fig. 7; a PWM generator using an IC comparator is illustrated in fig. 8.

Use the nearest standard value (270 ohms). When transistor Q1 is *on* and Q2 is *off*, point D will be at 11.7 volts (12-0.3). Since this is greater than the 11.3-volt saturation voltage, transistor Q3 should be cut off.

A similar process is used to choose a value for R2 (6800 ohms), assuming that point A is also driven by a complimentary pair. Note that although transistor Q1 does not conduct any sustained current, it will conduct the same surge current while switching, so R1 should be the same value as R2. A complimentary pair (such as Q1 and Q2) will generally be necessary for high switching speeds. If you use a single transistor and collector resistor, turn-on will be fast. However, turn-off will be slow because the collector capacitance must discharge through the resistor.

An emitter follower pair cannot provide any voltage gain, and will produce a smaller voltage swing in the output, and thus be less efficient. For these reasons a voltage gain pair is usually better. However, there are disadvantages. If point A is disconnected from its drive, both Q1 and Q2 will turn on, causing a short circuit, probably destroying themselves and Q3 as well. During switching this same process can cause a large current spike, reducing efficiency. It is generally a good idea to put a small resistor (1% to 5% of R3) somewhere in the collector path to reduce these effects.

Transistor base capacitance can be a significant impediment to high-speed switching. Before a transistor can turn on, its base capacitance must be charged to 0.7 volt through the base resistor. This produces an output waveform delayed from the driving waveform. This effect can be overcome by using speed-up capacitors (C1, C2 and C3 in **fig. 9**). These capacitors have much the same effect as the trimmer capacitor in an oscilloscope probe. The correct capacitance value causes a square-wave voltage (rather than a damped voltage) to appear on the base.

It is probably possible to calculate the values of these capacitors, but it is much easier to find the values by trial and error. Use an oscilloscope to compare the rising edges of the square waves at points A and D. Install capacitors C1 and C2 and observe that the delay becomes smaller; increase the value of C1 and C2 until the delay is negligible. Do not use more capacitance than is necessary as this will load the driver and slow the amplifier. Base-to-emitter resistors (such as R5) may be added to provide return paths for the speed-up capacitors. This helps to keep the transistors *off* when not driven *on*. Typical values (determined experimentally) are one-half to one-third of the corresponding base resistors.

One last comment on pulse amplifiers. Fixed voltage changes can sometimes be made by using diode drops. The diode(s) will conduct only when the applied voltage is large enough.

efficiency

What efficiency can you actually expect? Both saturation voltage and non-instantaneous switching reduce the efficiency of the output stage, and these and current spikes reduce the efficiency

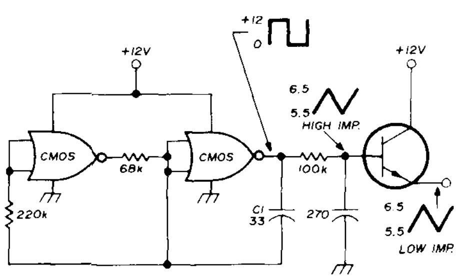


fig. 7. Simple reference triangle wave generator uses two cmos gates and one transistor.

of the driver stages. The driving resistors also consume power. Although exact calculation of efficiency requires some complicated formulas, here are some rules of thumb that give ballpark answers:

1. Decrease the efficiency of the output stage by subtracting the saturation voltage-to-V_{cc} ratio from 1. If the satura-

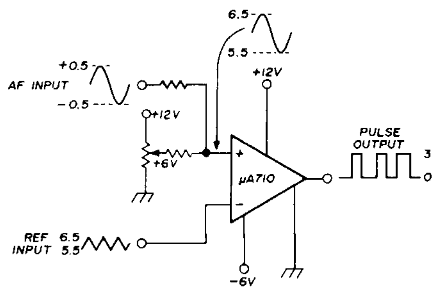


fig. 8. Simple IC comparator circuit generates PWM signal. Reference triangle waveform is provided by circuit of fig. 7. Input and output waveforms are shown in fig. 6.

tion voltage is 0.3 volt and the supply is 12 volts,

$$\eta = 1.00 - \frac{0.3}{12} = 1.0 - 0.025 = 97.5\%$$

2. Further decrease the efficiency by subtracting the ratio of the time spent in switching to the switching period. If the switching frequency is 100 kHz (10 μs) and the rise time is 100 nanoseconds,

$$\eta = 0.975 - \frac{2 \cdot 100 \text{ nsec}}{10\ \mu\text{sec}} = 95.5\%$$

3. Most of the power dissipated in the amplifier will be dissipated in the output stage and its base driving resistor(s). The power consumed in the base resistor is approximately equal to the output power reduced by the ratio of base current to output current. This decreases the efficiency by the ratio of i_b to i_c (or by $1/\beta$)

$$\eta = 0.955 - \frac{41 \text{ mA}}{1 \text{ A}} = 91.4\%$$

Remember that these rules are only approximate, so the actual efficiency will be lower at less than peak output. Before you get discouraged, though, remember that saturation voltage and drive power reduce class-B efficiency, and that peak power contributes most to the average efficiency.

power regulators

Class-D operation can also be used for ac and dc power control. SCRs and triacs can be used to chop an ac waveform to produce the desired output power. These devices turn on when driven and stay on until the output current ceases (at the end of an ac half cycle). SCRs conduct current in only one direction, while triacs conduct current in either direction.

Dc voltages (or currents) can be regulated efficiently by switching regulators.[10,11] A voltage-reducing regulator circuit looks like a simplified audio amplifier (**fig. 10**). The high-gain amplifier compares the output of the lowpass filter to the desired reference voltage. If the output voltage is lower than the reference by more than a small amount, transistor Q1 is turned on and the output voltage begins to rise. When the output voltage exceeds the reference by more than a small amount, Q1 is switched off and the output begins to fall. In this manner the output voltage is kept within a small fixed amount of the reference voltage. The switching frequency depends on the output filter and current, and varies with changing load conditions. The high-gain amplifier and voltage reference

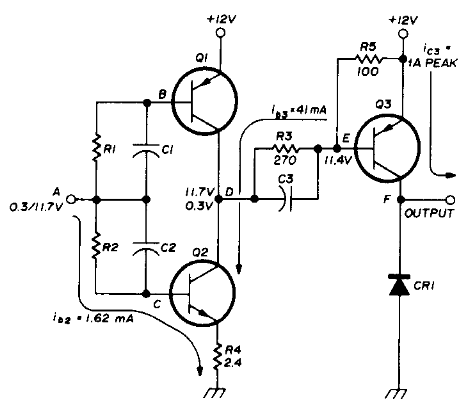


fig. 9. Basic pulse amplifier circuit. Design and operation of this circuit is discussed in the text.

are often available in a single IC such as the μA723.

class-D rf amplifiers

Class-D operation can also be used to build high-efficiency rf amplifiers.[12] In this case the switching frequency component of the pulse train becomes the rf carrier and is coupled to the load through a bandpass filter rather than a lowpass filter. **Fig. 11** shows the equivalent circuit of a simple class-D rf amplifier. Switches S1 and S2 (switching transistors in an actual circuit) are driven alternately on and off with a 50% duty cycle, producing a square-wave voltage, V_s. The square-wave voltage has components at the fundamental (switching) frequency and its odd harmonics. The peak-to-peak voltage of the fundamental component is $4/\pi$ (1.27) times the peak-to-peak voltage of the square wave. The series-tuned output circuit is resonant at the switching frequency, so it exhibits high impedance to the harmonics, but provides a direct connection to the load for the carrier. As a result, only current at the carrier frequency can flow into the load.

The output voltage and current are sine waves which are represented mathematically by

$$v_o = \frac{2V_{cc}}{\pi} \sin \omega t$$

$$i_o = \frac{v_o}{R} = \frac{2V_{cc}}{\pi R} \sin \omega t$$

When the output current, i_o, is positive, it flows through S1; when it is negative, it flows through S2. A single transistor switch cannot be used for class-D rf operation because the output current must be able to flow in both directions. The power output from this amplifier is given by

$$P_o = \frac{(v_{o\,peak})(i_{o\,peak})}{2} = \frac{2V^2_{cc}}{\pi^2 R}$$

The switches consume almost no power themselves because the voltage across them is nearly zero when they are conducting current.

rf circuits

There are a variety of class-D rf amplifier circuits **(fig. 12)** just as there are a wide variety of linear amplifiers. The equivalent circuit just discussed can be realized by any of the complimentary versions **(figs. 12A, 12B** or **12C)**. The input transformer secondary windings are

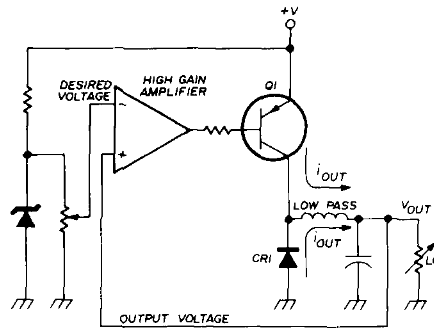


fig. 10. Basic switching voltage-regulator circuit.

connected so that the transistors turn on with opposite polarities of the drive signal. Complimentary class-D amplifiers have the advantage of requiring no output transformer, and hence no transformer losses.

The quasi-complimentary configuration **(fig. 12C)** uses only npn transistors which are both more abundant and less expensive than pnp types at high frequencies. This is a definite advantage of the quasi-complimentary circuit.

Transformer-coupled or push-pull class-D amplifiers are also possible. In the voltage-switching amplifier **(fig. 12D)**, alternately driving the transistors *on* causes their collector voltages to be square waves of zero to $2V_{cc}$ volts. The current which flows in either transistor is a half cycle of a sine wave, just as in the complimentary amplifiers. Power output depends on the turns ratio of the output transformer, as well as on the supply voltage and load resistance.

The total voltage swing on the transformer primary is $2V_{cc}$, so if there are four turns in the primary for each turn in the secondary, the output power will be the same as that of a complimentary amplifier. Output voltage varies with the turns ratio, and output power varies with the square of the turns ratio. The turns ratio can be used as part of the matching and loading network. This configuration is particularly useful when the supply voltage is low since it provides a $2V_{cc}$

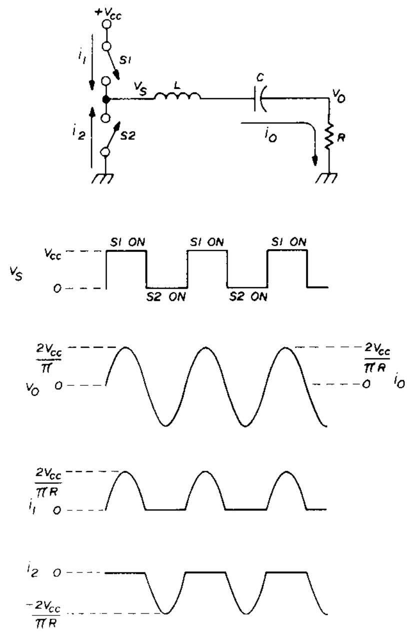


fig. 11. Equivalent circuit of a class-D rf amplifier and ideal waveforms.

voltage swing at the collectors of the power transistors.

This is a good time to point out that you cannot connect an rf choke directly to the collector or primary center tap in a voltage-switching amplifier (**fig. 12A, 12B, 12C** or **12D**). These amplifiers draw current in lumps at the signal frequency, and an rf choke tries to force constant current. A capacitor should be connected from either the collector of transistor Q1 or the primary center tap to ground to supply current as needed while maintaining constant voltage. An rf choke can then be connected from the collector to the supply to keep rf out of the power supply.

Another class-D rf circuit is the current-switching push-pull amplifier shown in **fig. 12E**. This circuit is a so-called "dual" of the voltage-switching amplifier because it features square-wave current and sine-wave voltages. The rf choke forces a constant current so the transistors conduct constant current while they are *on*. The parallel-tuned output filter conducts all of the harmonic currents but forces the carrier current into the load. Output voltage and power are somewhat different than those of the voltage-switching amplifier. Since there can be no dc voltage drop across a transformer winding, the total primary voltage must be

$$v_{pri} = \pi V_{cc} \sin \omega t$$

(The peak collector voltage is πV_{cc} so the average or dc collector voltage is V_{cc}.) If the turns ratio is 1:1, the output power is

$$P_o = \frac{\pi^2 V^2{}_{cc}}{2R}$$

Output current is

$$i_o = \frac{\pi V_{cc}}{R} \sin \omega t$$

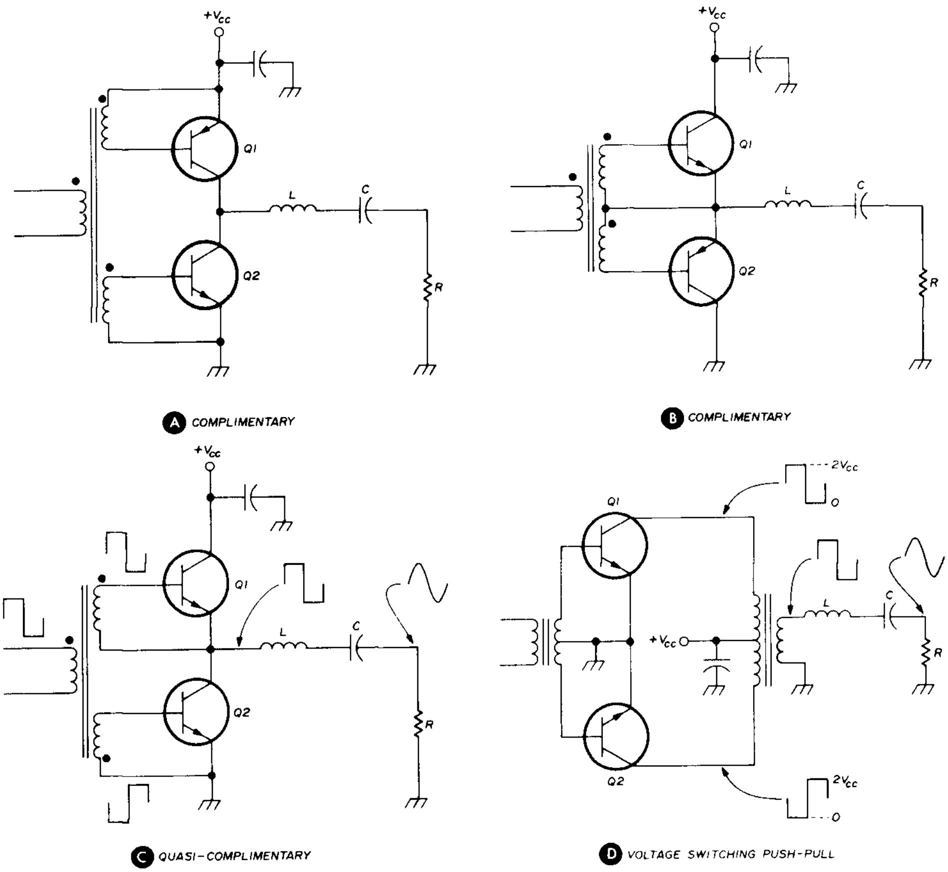
and the dc input current (and transistor peak current) is

$$I = \frac{\pi^2 V_{cc}}{2R}$$

The current-switching amplifier offers an alternative way of fitting together power requirements, supply voltage and maximum transistor ratings. Also, it has the same configuration and the same output filters as class-B transistor power amplifiers. However, it will generally be less efficient than the voltage-switching amplifier because more current must be drawn through the same saturation voltage and large amounts of current must be switched (the voltage-switching amplifier switches at zero current points).

transformers and tuned circuits

The transformers required in class-D rf amplifiers are essentially the same as



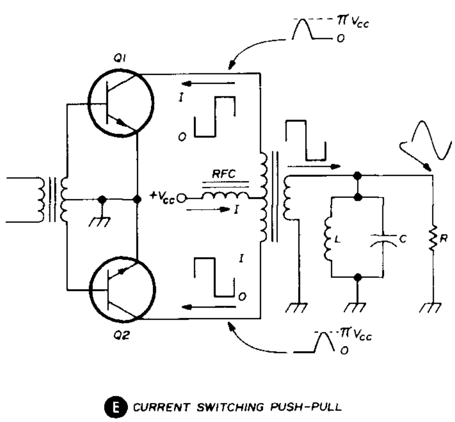


fig. 12. Practical class-D rf amplifiers can be built in various ways as shown here. The advantages and disadvantages of each of these circuits are discussed in the text.

those used in solid-state class-B rf amplifiers.[15] They consist of several parallel wires wound on a stack of toroidal cores made of suitable material for the frequencies to be used. Building these transformers is a mixture of intuition and witchcraft and a lot of trial and error. However, here are some general rules:

1. Increasing the number of turns increases the series inductance, degrading the high-frequency response.

2. Paralleling two windings with the same number of turns decreases series inductance, improving high-frequency response.

3. Stacking several cores increases power handling capability and increases shunt inductance, improving low-frequency response.

The transformer parameters must be chosen to fit the application, and in class-D circuits it is necessary to pass a few harmonics of the carrier as well as the carrier itself. However, it is not difficult to build transformers working over several octaves (up to 5 or 6).[16,17]

The output filter need not be the simple tuned circuits used in the examples here. A T-network presents a high impedance to the harmonics of the carrier, and can be used where series-tuned circuits are shown. Pi-networks present low impedances to the harmonics and can be used in the place of parallel-tuned circuits. Input impedance to the third harmonic should be at least ten times the load impedance at the carrier frequency, and the output filter should attenuate harmonics by 50 dB or more.

Two (or more) small amplifiers can be combined to obtain greater output power by connecting them to the load through a hybrid transformer (**fig. 13**) as is done with linear amplifiers.[18] Basically, a hybrid transformer prevents the two amplifiers from loading each other. The transformer has a 1:1 turns ratio which forces equal currents in each winding. If you wish, you can work out the details with a little algebra, but essentially, if the two amplifiers do not produce equal outputs, R2 consumes power and reduces efficiency. This means the two amplifiers must be closely matched or controlled.

Hybrid transformers are also used to divide drive power between two amplifiers whose outputs will be combined. This helps to keep phase relationships the same in each amplifier. If more than two *amplifiers are to be combined, they must*

table 1. Transistor types that are suggested for use in high-efficiency class-D amplifiers. However, these are not the only ones that can be used. Avoid using rf transistors which are optimized for particular frequencies as they usually contain internal matching which usually won't help them switch fast. These specs are intended as a general guide rather than exact specifications.

JEDEC number	type	maximum V_{CE}*	maximum I_C	package	application
2N4123	npn	30	0.2	TO-92	100-kHz switch
2N4124	npn	25	0.2	(plastic)	
2N4125	pnp	30	0.2		
2N4126	pnp	25	0.2		
2N2222A	npn	40/65**	0.8	TO-18	1-MHz switch
2N2907A	pnp	40/65**	0.8	(metal)	
2N5190	npn	40	4.0	flat	100-kHz switch
2N5191	npn	60	4.0	(plastic)	
2N5192	npn	80	4.0		
2N5193	pnp	40	4.0		
2N5194	pnp	60	4.0		
2N5195	pnp	80	4.0		
2N3262	npn	80/100	1.5	TO-39	
2N3734	npn	30/45	1.5	TO-5 (metal)	30-MHz switch (high-speed switch)
2N3735	npn	50/70	1.5		
2N5262	npn	50/70	3.0	TO-39	
2N3961	npn	40/56	1.0	stud	30-MHz switch (400-MHz rf)
2N3553	npn	40/56	1.5	can	
2N3375	npn	40/56	1.5	stud	
2N3632	npn	40/56	3.0	stud	
SD-200	fet	25	0.05	can	100-MHz switch
1N4933	diode	50	1.0	DO-41	100-kHz switch
MR380	diode	50	3.0	(metal)	

*When two values are shown they are V_{CBO}/V_{CEV}. The first is with base open, the second with reverse bias as in a push-pull amplifier.

**Without A suffix, 30/50.

be combined in groups of two. The drive signal is first split into two signals, then into four. Two pairs of outputs are combined to form two signals; these signals are then combined to form one high-power output. Note that the input impedance of the hybrid transformer and the difference load resistor are twice the output resistance.

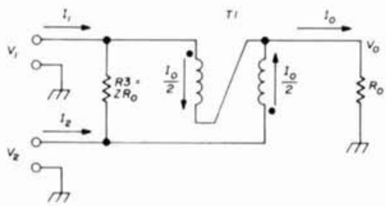


fig. 13. Hybrid transformers, such as the one shown here, can be used to combine the outputs from two amplifiers.

class-D rf amplifier design

Designing a class-D rf amplifier is generally easier than designing a class-B or -C rf amplifier stage. There are no gain-variation, base-bias, neutralization or unequal-current problems to worry about. As with class-D audio amplifiers, you start at the output and work backwards.

I decided to try to design and build a 50-watt class-D power amplifier for 160 and 80 meters (and maybe 40). The circuit that resulted is shown in **fig. 14**. The first step is selecting the Q of the output circuit. I chose a Q of 5 which meant that L3 and C6 must have reactances of 250 ohms at the midband frequency. This value of Q reduces the third harmonic to 33 dB below the carrier.

The next step is to determine the output voltage and current. The peak voltage and peak current into the 50-ohm load are found from

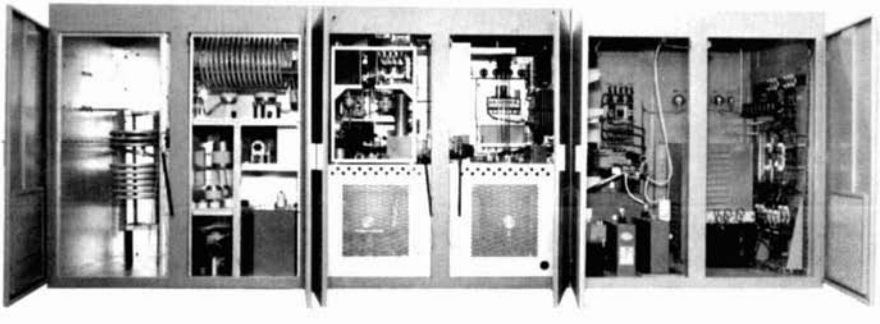
$$v_p = \sqrt{2RP} = \sqrt{2 \cdot 50 \cdot 50} = 70.7 \text{ volts}$$

$$i_p = v_p/R = 70.7/50 = 1.41 \text{ amp}$$

The peak value of square-wave voltage at the input of the tuned circuit which will produce this peak output is

$$v_{swp} = \frac{\pi}{4} \cdot 70.7 = 55.5 \text{ volts}$$

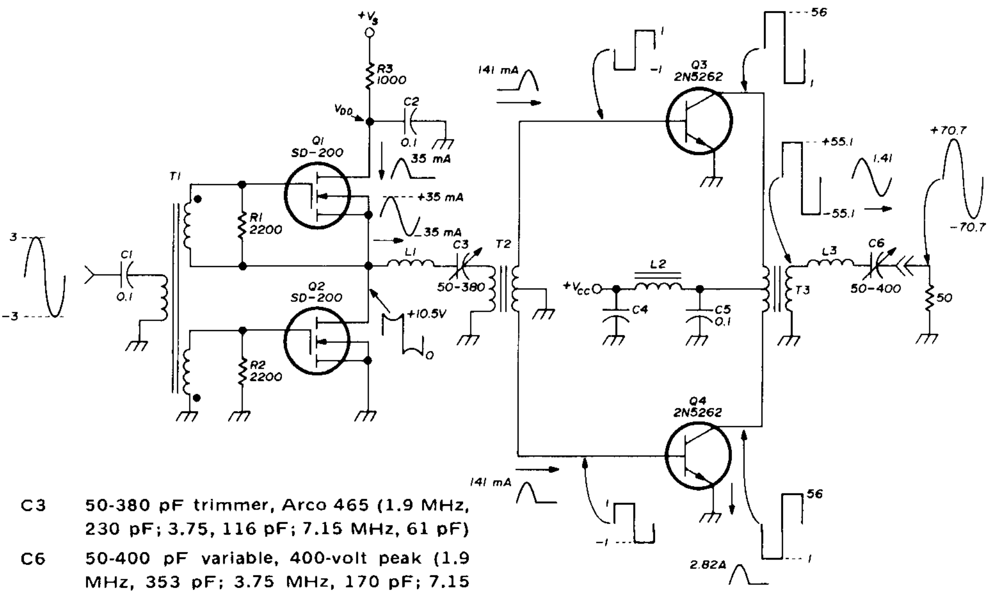
If no matching were used, the transistors would have to withstand 111 volts or



The Gates Radio Company VP-100 is a 100-kW a-m broadcast transmitter which uses a class-C rf amplifier and a class-D modulator. The modulator switches at 75-kHz and has an efficiency of about 90%. Overall efficiency is about 65%. The rf output circuitry is on the left, the PA and modulator are in the middle, and the power supplies are on the right.

more on their collectors. It is convenient to use a 4:1 matching transformer which reduces the square-wave voltage swing to 27.8 volts and increases peak current to 2.83 amps. These values are much more suitable for commercially available transistors.

I decided on the push-pull circuit rather than the quasi-complimentary configuration because I was already using a matching transformer and because a 28-volt power supply is easier to come by than a 56-volt supply. Capacitor C5 provides an ac ground for the transformer center tap,



C3	50-380 pF trimmer, Arco 465 (1.9 MHz, 230 pF; 3.75, 116 pF; 7.15 MHz, 61 pF)	
C6	50-400 pF variable, 400-volt peak (1.9 MHz, 353 pF; 3.75 MHz, 170 pF; 7.15 MHz, 89 pF)	
L1	160 meters	63 turns no. 30 on Permacore 57-1753 core (30.5 μH)
	80 meters	44 turns no. 26 on Permacore 57-1753 core (15.4 μH)
	40 meters	36 turns no. 26 on Permacore 57-1677 core (8.1 μH)
L2	16 turns no. 26 on Permacore 56-3596 ferrite core (1.0 μH)	
L3	160 meters	52 turns no. 26 on Permacore 57-1753 core (20.9 μH)
	80 meters	42 turns no. 26 on Permacore 57-1677 core (10.6 μH)
	40 meters	30 turns no. 26 on Permacore 57-1677 core (5.6 μH)
T1	primary is 5 turns no. 26 enamelled on Ferroxcube 226T125-3E2A ferrite core. Secondary windings are each 25 turns no. 26 on same core	
T2	primary is 8 turns no. 20 enamelled wire wound through 6 Ceramic Magnetics CN-20 cores (two parallel stacks). Secondary is 4 turns no. 20, center-tapped, through same cores (see text)	
T3	primary is 4 turns no. 20 enamelled wire, center-tapped to C5, wound through 12 Ceramic Magnetics CN-20 cores (two parallel stacks). Secondary is 4 turns no. 20 through same cores (see text and fig. 15)	

fig. 14. Class-D rf power amplifier for 160, 80 and 40 meters provides more than 35 watts output with collector efficiencies of 90% or more. Construction of transformer T3 is shown in fig. 15.

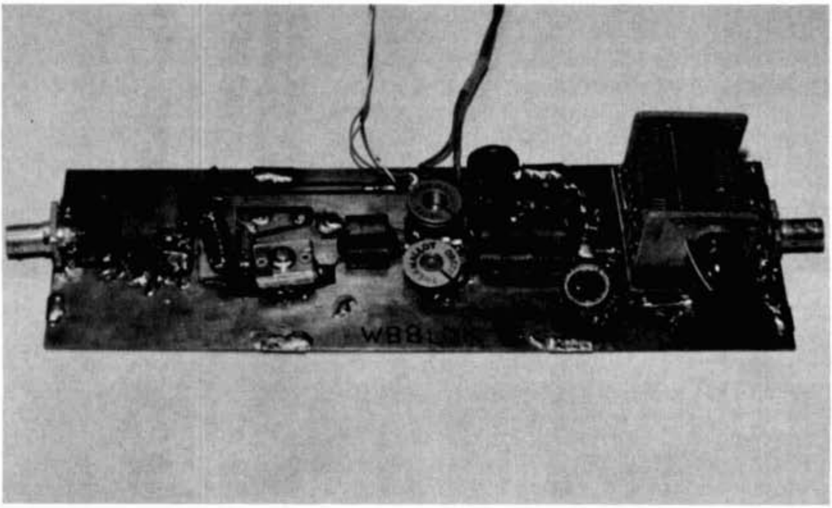
If the saturation voltage is 1 volt, the collector supply voltage, V_{cc}, must be 28.5 volts, and the collector voltage will swing between 1 and 56 volts. The dc current required is

$$i_{dc} = \frac{2i_p}{\pi} = \frac{2 \cdot 2.83}{\pi} = 1.80 \text{ A}$$

and the L2-C4 combination keeps rf out of the power-supply wiring.

Now the driving circuitry must be designed. It is convenient to drive the bases of transistors Q3 and Q4 through a push-pull transformer to insure that they are driven out-of-phase with respect to each other. It is best to drive the bases with sine-wave current.

While square-wave current might turn the transistors *on* a little more rapidly, it maintains a lot of charge in the base which must be removed before the transistors will turn *off*. A check of switching



Author's experimental class-D power amplifier. Parts are in the same general locations as in the circuit diagram (fig. 14). Note that C6 is elevated by pieces of PC board.

transistor characteristics will show that storage time (turn-off delay) is a much more serious problem than turn-on delay. Sine-wave current provides the base with only enough charge to sustain the collector current, greatly reducing storage-time effects.

If the output transistors have a current gain of 20, to insure saturation the base current in each transistor must be a half sine-wave with a peak value of

$$i_{bp} = \frac{2.83}{20} = 142 \text{ mA}$$

The base voltage will rise to about 1 volt (or slightly less) when driven. When the current changes direction, the base becomes an open circuit and its voltage becomes −1 volt. This is a reflection of the +1 volt potential on the base of the other transistor through transformer T2. The power which must be applied to the two transistor bases is then

$$P_b = \frac{\frac{4}{\pi} \cdot 1 \cdot 0.142}{2} = 90 \text{ mW}$$

This means that the power amplifier has a power gain of about 27 dB!

Since the drive power is only a small fraction of the total power this amplifier will require, driver efficiency is not too important. Almost any type of rf amplifier can be used for a driver — even untuned class-A. I found it more convenient to use a quasi-complimentary class-D amplifier. I used a pair of relatively new fets for Q1 and Q2. These have greater stability and faster switching speed than most bipolar devices, and are easier to drive as well.

The series-tuned circuit L1-C3 will allow only sinuosidal current to flow. Since harmonic suppression is not as important as in the power-amplifier stage, I used a Q of 2.5 for the driver. At the carrier frequency transistors Q3 and Q4 have a base resistance of

$$R_b = \frac{(4/\pi) \cdot 1}{0.142} = 8.97 \text{ ohms}$$

It would be difficult to build a 90-mW

driver with a 9-ohm load line, so T2 has a turns ratio of 4:1. This multiplies the impedance by 16, resulting in a 145-ohm load line. The ±1 volt base voltage will become ±4 volts on the input of T2. The current input to T2 has peaks of about 35 mA.

When saturated, the fets become 45-ohm resistors. This causes a voltage drop. To correct for this voltage drop, it is necessary to increase the supply voltage, V_{DD}. If there were no voltage drop through the fets, V_{DD} would be 8 volts to allow a ±4-volt swing. With the correction,

$$V_{DD} = 8 \cdot \frac{145 + 45}{145} = 10.5 \text{ volts}$$

The driver dc input current is 11.1 mA ($35/\pi$) so the driver power input is

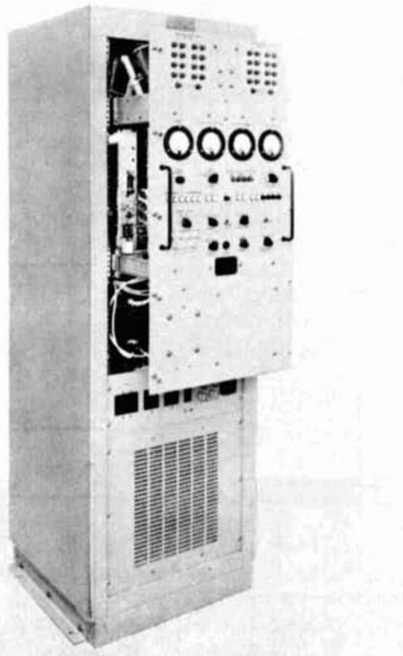
$$P_D = (10.5)\,(0.011) = 117 \text{ mW}$$

The driver efficiency is about 77%.

It is not a good idea to try to operate the driver from a 10.5-volt power supply. Remember that the value of 10.5 volts is related directly to the nominal 1-volt base saturation voltage. This was not an exact value to start with, and even if it were, it would vary slightly with temperature, collector current, etc. If V_{DD} were fixed at 10.5 volts and the base voltage decreased slightly, only the fet saturation resistance would limit the current. For this reason, it is better to use a higher voltage supply, V_s, and to provide a resistor to absorb changes in the base voltage. I used a 1k resistor and a 21.6-volt supply, which made it easy to monitor drive current. With this resistor the overall drive efficiency is about 37%, but the 240-mW total drive power is still less than one-percent of the power-amplifier power.

The fets are saturated by applying a 15-volt peak sinusoidal gate-to-source voltage. The 1:5 turns ratio of T1 permitted driving them from a 3-volt source. Since the fets have a very high input impedance and require essentially no input power, it was necessary to load the secondary windings to produce an approximate 50-ohm input impedance.

Transformers T2 and T3 are made by running enamelled wire through two parallel stacks of ferrite cores as shown in **fig. 15**. Transformer T3 has four turns in the output winding and two turns in each side of the input; T2 has two turns in each side of the output and eight turns in the input winding. Since I had the smaller size cores, twelve cores were required for



The Continental Electronics 314(E) is a 2-kW CW/MCW all solid-state transmitter for 275 to 530 kHz. It uses a push-pull class-D rf amplifier, and has an overall efficiency of 70% or better with load vswr as high as 3:1. Photo courtesy J.D. Rogers.

T3 and six for T2. The length of the individual cores is not important but the length of the transformer is, so if you have longer cores, use fewer of them. Both T2 and T3 show a phase angle of 10° or less on 160 and 80 meters. On 40 meters and up, series inductance appears. The series-tuned circuits can tune out this inductance on a particular frequency.

Two possibilities for Q3 and Q4 are the 2N5262, a switching transistor, and the 2N3632, an rf transitor. Either transistor should handle the required current and voltage. Since 2N5262s were considerably cheaper, I decided to use them. It's my guess that rf transistors would be less efficient but more rugged. Clip-on heatsinks will reduce thermal stress on Q3 and Q4.

My amplifier was built on a double-sided PC board to insure a good ground plane. Layout is not critical, but remember that a 1.8-MHz class-D amplifier contains energy at frequencies much higher than 1.8 MHz.

The driver and power amplifier tuning coils are wound on 0.680-inch (17-mm) OD rf toroid cores. All have a measured Q of 190 or more. The Q of these inductors is very important since it determines the amount of power they absorb from the output. The fraction of power lost to the coil is the ratio of circuit Q (5 for the output) to the inductor's unloaded Q. An inductor with a Q of 200, for example, causes a 2.5% reduction in efficiency. Remember that winding coils, like winding transformers, is a black art. Don't think you can improve the Q by using larger wire – you will decrease the self-resonant frequency and the Q because the interwinding capacitance is increased.

Test the driver first, with power removed from the power amplifier stage. Tune the driver for peak input current (if tuning for peak current seems strange, remember that this is series tuned, whereas most class-C power stages are parallel tuned). Input current should not exceed 16.6 mA, as this corresponds to the 50-mA peak current rating of the fet. Also, V_S should be kept at 25 volts or less. If the bases of Q3 and Q4 suddenly open, V_{DD} will go up to V_s. The driver should work on 160, 80 and 40 meters. It will also work on 20 if you reduce L1 to compensate for the series inductance of T2. You can tell when the input signal is large enough by whether any further increases produce increases in the dc current.

Now for the final. *Always* turn the driver on first (and off last). This circuit is not designed to have both Q3 and Q4 on at the same time, so it will oscillate, probably destroying the transistors. Start V_{cc} at zero and bring it up to 3 or 4 volts so you can measure the output. In the absence of an output meter, tune for peak dc current. Tune the power amplifier only at very low voltages. When the

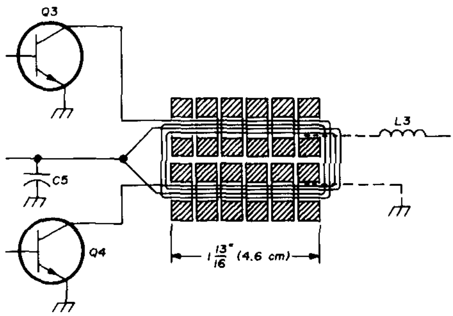


fig. 15. Layout of the output transformer (T3 in fig. 14). Primary is 4 turns no. 20 enamelled, center-tapped to C5, wound through 12 CN-20 ferrite cores (two parallel stacks). Secondary is 4 turns no. 20.

load is reactive (mistuned), large voltage spikes are generated, and these will usually destroy the transistors. After the stage is tuned up, increase V_{cc} gradually. Check to see that Q3 and Q4 are saturated by slightly varying the drive (V_S). If there is any variation in the output power or dc input to the final, it needs more drive.

I first tested the amplifier at the 10-watt level on all three bands. I measured collector efficiencies of 95%, 92% and 89% on 160, 80 and 40 meters, respectively. As you increase V_{cc}, efficiency will improve because the saturation voltage becomes less significant. The power supply I was using was limited to 1.5 amps so the transmitter was limited to an output of 38.5 watts on 160 meters. To obtain this output, however, I had to increase the drive to its maximum (16.6 mA dc input). The specified current gain of the 2N5262 is 25 at 1 amp of collector current. Apparently the current gain drops to approximately 10 at 2.5 to

3 amps of collector current. On 80 meters an output of 32 watts required maximum drive. Winding T2 with a 5:1 turns ratio would probably provide enough drive for 50-watts output.

I tried the amplifier on 20 meters and this eventually resulted in two dead transistors. Although the bottom of the collector voltage waveform remains square, ringing due to transformer inductance and stray capacitance continues for most of the time the transistor is off. Although I measured 63% efficiency at about 1-watt output, the amplifier has a tendency to oscillate and to divide frequency. However, I think the circuit would work on 20 meters with different transformers. The series inductance can only be tuned out at the fundamental frequency, and the reactances at the harmonic frequencies make it difficult to obtain the half-sinusoidal current waveforms required in class-D operation.

The variation of output voltage with supply voltage is very linear, and driver feedthrough is only a few milliwatts, so the power amplifier should be suitable for a-m or ssb service (using the EER technique). It might be a good idea to include an automatic phase comparison circuit which would reduce the collector voltage when the output was mistuned (reactive). Such a circuit would be essentially the same as the vswr protection circuits used in early solid-state rf power amplifiers.

modulation

All of the class-D rf amplifiers discussed so far are constant carrier (amplitude) types. If these amplifiers are to be used for a-m or ssb service, they must be modulated. Modulation is most easily accomplished by varying the collector supply voltage with a class-D audio amplifier. For ssb service, this is an application of the envelope elimination and restoration technique discussed earlier. The use of both class-D audio and rf amplifiers produces a highly efficient linear rf amplifier. Collector modulation of the class-D rf amplifier is very linear and there is no need to modulate the driver (in a class-B or -C amplifier, both the power amplifier and the driver must be modulated to prevent overdrive).[14]

Pulse-width modulation can be adapted to produce a modulated rf carrier as shown in **fig. 16**. Because the carrier component of a pulse train is proportional to the sine of the pulse width, rf pulse-width modulation (PWM) must be generated by comparing the desired modulation to a full-wave rectified cosine wave at the carrier frequency. The output amplifier may be either monopolar or bipolar.[13]

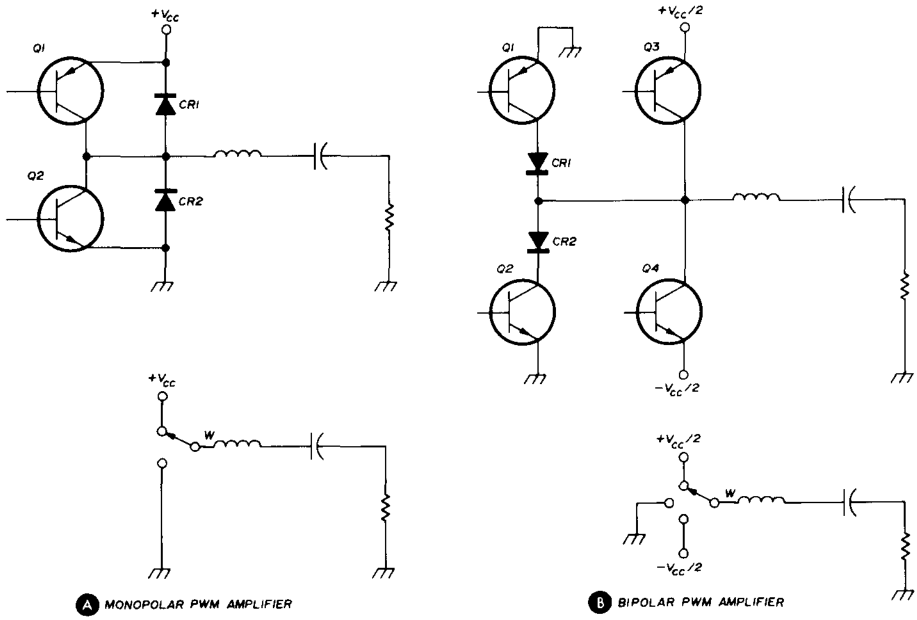
Bipolar rf PWM has essentially no splatter due to non-linear modulation of the harmonics of the carrier. Although the rise times required by rf PWM are no higher than those required by a constant-carrier class-D rf amplifier, rf PWM requires switching stages to be controlled as in audio PWM, and this makes it much more difficult to implement. You might be able to build an rf PWM amplifier for operation on 160 meters, but with present devices, it would be difficult to use at much higher frequencies.

vacuum-tube circuits

If you are thinking about a legal limit transmitter, you might consider using vacuum tubes. Power handling capabilities are much greater than those of transistors, and filament power need not be counted as part of the input power. The same configurations apply to tubes as well as to transistors. A vacuum tube can be turned off quite efficiently by driving the grid negative, and this consumes very little power. Driving the grid positive forces the tube to saturate, causing it to act like a resistor. However, driving the grid positive causes grid current to flow and consumes drive power.

What you can obtain with tube switches must be determined by using the characteristic curves of the tubes you plan to use. Generally the saturation losses will be greater than those of transistor amplifiers. However, the output matching networks may be more efficient, and saturation losses occur in class-B vacuum tube amplifiers as well as class-D amplifiers.

When an application calls for a power level or frequency where class-D operation is impractical, there are several other types of amplifiers which have efficiencies better than that of class-B. These include class-C, of course, and a couple of amplifier circuits which don't really operate as class-A, -B, -C *or* -D. Since the envelope elimination and restoration technique makes it possible to use nonlinear rf amplifiers in linear service it is possible to design the rf amplifier for efficiency rather than linearity.



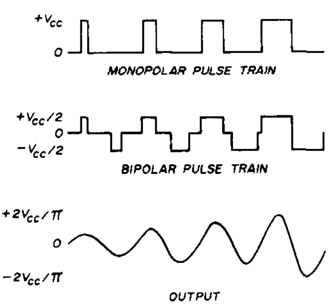


fig. 16. Radio-frequency pulse-width modulation system.

Class-C operation has been used for many years to build rf amplifiers with improved efficiency.[19,20] A class-C amplifier has the same basic circuit (**fig. 17**) as a class-A or -B linear amplifier, but it is biased and driven so the transistor conducts current for less than half the time. Current is thus drawn through the transistor when the voltage is lowest, resulting in less power consumption.

The reduced conduction angle can be obtained at various combinations of bias and drive, and the current pulse need not be exactly sinusoidal. There are some general rules for class-C operation:

1. Any deviation from class-B (or class-A) produces a nonlinear amplifier.

2. Reducing the conduction angle will improve the efficiency, with efficiency approaching 100% as the conduction angle approaches zero.

3. As the conduction angle is reduced, either output power will decrease or peak collector current will increase.

4. The necessary increase in drive power is approximately inversely proportional to the conduction angle.

These rules will help you to estimate what performance can be obtained by converting a class-B amplifier to class-C. Class-C can be used to obtain higher efficiency, but it won't be a panacea because drive requirements and peak current will increase with increasing efficiency.

envelope feedback

A technique called envelope feedback can be used to make a nonlinear rf amplifier operate as if it were linear, provided there is some sort of gain control which can be applied.[21] Basically, this technique uses a feedback loop to look at the desired output and the actual output, and correct amplifier gain so the two are equal.

Envelope feedback is not a new idea, but today it is much easier to implement due to the abundance of integrated circuits. It is no different from other audio feedback and requires a frequency response from dc to about 10 kHz for ordinary ssb signals. To keep the feedback loop from oscillating, it is necessary that the open-loop gain (point A to point E in **fig. 18**) be zero for frequencies with 180° or more phase shift. Many books have been written on feedback theory, so I will not go into it any deeper.

Class-C amplifiers are an ideal application of envelope feedback. The bias network normally used to bias a class-B transistor amplifier slightly into conduction can be eliminated and the resulting nonlinearity corrected by feedback. Eliminating the bias network will result in power savings without further reducing the conduction angle. A wide-range gain control must be used ahead of the power amplifier to reduce the drive. Another possibility is to control the bias of the stage itself; more negative bias means a smaller conduction angle and less output.

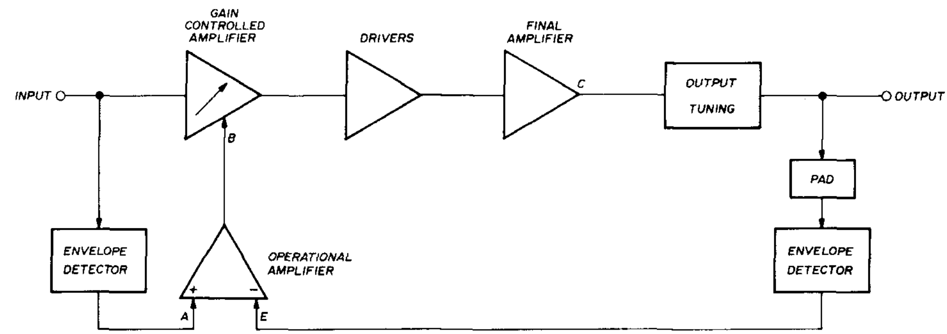


fig. 18. The envelope feedback technique shown here can be used to make a non-linear rf amplifier operate as if it were linear (see text).

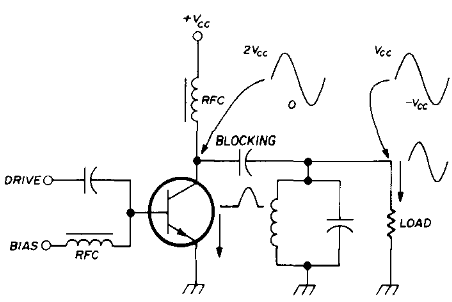


fig. 17. Basic solid-state class-C rf amplifier circuit.

multiple tuning

The multiply-tuned rf power amplifier uses only a single switching transistor and can (ideally) have an efficiency of 100 percent.[22,23] The transistor operates as if it were part of a class-D voltage-switching amplifier. When the transistor is *off*, the current path is provided by a complex tuning network rather than a second transistor. This type of amplifier has been given a different name by practically every author who has written about it; some of the names are: optimally-loaded and overdriven class-B, multiple-resonator class-C, single-ended class-D, and class-CD. My own name is class-E. This technique is particularly useful at vhf where driving a pair of transistors 180° out of phase becomes difficult.

A voltage-switching class-D amplifier has a *square-wave voltage and half-wave* rectified sine-wave current, arranged so that one or the other is always zero in each transistor. Examination of the waveforms reveals that the voltage waveform contains a fundamental and *odd* harmonics, while the current waveform contains a fundamental and *even* harmonics. To maintain both waveforms with a single transistor requires an output network which is resistive at the carrier frequency, a short-circuit to even harmonics, and an open-circuit to odd harmonics. The series of parallel-tuned circuits in **fig. 19** pass even-harmonic current freely while preventing odd-harmonic current from flowing. The parallel-tuned output circuit passes the even-harmonic current to ground and forces the fundamental frequency current into the load. Ideally, the transistor consumes no power since it always has either zero voltage or zero current.

When this technique is used at lower frequencies, only resonators for the fundamental frequency and third harmonic are usually used, and the circuit is referred to as "third-harmonic peaking." Efficiencies of 90-percent have been reported.

At higher frequencies the series of parallel-tuned traps can be replaced by a quarter-wavelength transmission line as shown in **fig. 20**. The parallel-tuned output circuit provides a short-circuit to all harmonics. The quarter-wave line transforms the short-circuit into an open-circuit for odd harmonics and a short-circuit for even harmonics. *In addition, it* can be used to transform the actual load resistance to the desired load line. If the characteristic impedance of the line is R_o, and the actual load resistance is R_L, the load line is

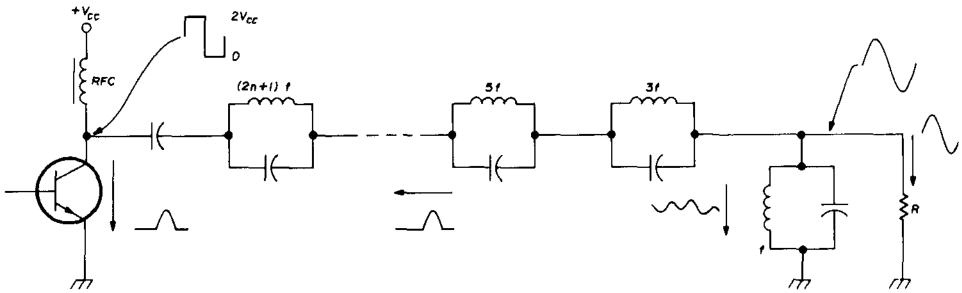


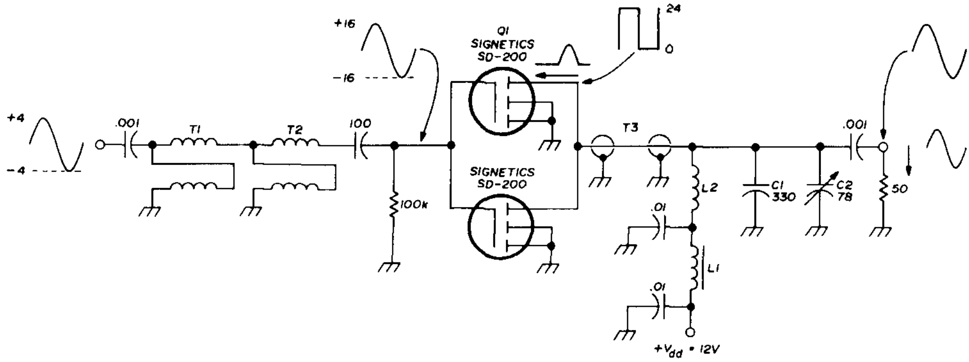
fig. 19. Basic multiple-resonator rf power amplifier. Practical circuit is shown in fig. 20.

$$R = R_o^2/R_L$$

The circuit shown in **fig. 20** can be adapted to a 300-mW walkie-talkie for 10 or 6 meters (or 2 or 1¼ meters, too, if you're very careful about how you put it together). I tested it at 25 MHz and measured 73% efficiency.* The output circuit has a Q of 3, and the transmission-line transforms the 50-ohm output to a 300-ohm load line.

When saturated, the fet becomes a resistor (about 45 ohms in this case). Since the fet requires negligible drive power, it should be possible to obtain the 16-volt peak sine-wave drive directly from the oscillator tank circuit, eliminating the need for a driver. Remember that matching could also be accomplished with a pi-network—this would allow the use of other transmission-line impedances.

*This circuit was the author's entry in Signetics' D-mos fet contest and will be the subject of a future Signetics Applications Note.



C2	78-pF variable (E.F. Johnson 158-4)		T1,T2	11 turns no. 26 twisted pair on Perma-core 57-2656 or Micrometals T30-6 core
L1	2.2 μH rf choke (Delevan 1025-28)			
L2	106 nH (4 turns no. 26 wire on Perma-core 57-2656 or Micrometals T30-6 core)		T3	piece of 125-ohm coaxial cable (RG-63B/U), 112.2" (2.85 meters) long

fig. 20. This 300-mW multiply-tuned rf amplifier designed for operation on 25 MHz has efficiency of 73%. In this circuit transformer T3 is a section of coaxial transmission line.

capacitor-shunted switch

The capacitor-shunted switching (CSS) amplifier is another type of rf amplifier which uses a single switching transistor and doesn't behave like any of the four standard amplifier classes.[24] I sometimes call it class-F (for far-out). Instead of regarding collector capacitance as an impediment to its operation, the CSS amplifier uses it as an integral part of the circuit.

The shunt capacitor (**fig. 21**) provides a current path when the transistor is *off*. The rf choke acts as a constant dc current source. The series-tuned circuit forces sinusoidal current to flow into the load, and has a high input impedance to harmonic voltages. The difference between the current flowing into the circuit through the rf choke and that flowing in the output either flows through the transistor (when it is *on*) or charges the capacitor (when the transistor is *off*). The fundamental frequency component of the collector voltage is the voltage which appears across the load.

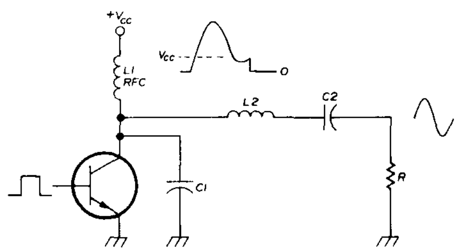


fig. 21. Capacitor-shunted switching (CSS) amplifier can provide operating efficiencies of nearly 100%.

Any energy stored in the capacitor at the time the transistor switches *on* will be dissipated in the transistor. Recently, Sokal discovered that mistuning the resonant circuit so that it is inductive causes the capacitor voltage to drop to zero at the time the transistor switches on, producing 100% efficiency.[25]

Analyzing this amplifier is fairly complicated, but the resulting design equations given by Sokal are fairly simple:

$$L2 = \frac{Q\,R}{\omega}$$

$$C2 = \frac{1 + 1/Q}{\omega Q R}$$

$$C1 = C2 \cdot Q/6.3$$

$$P = \frac{2V_{cc}{}^2}{\left(\frac{\pi^2}{4} + 1 \quad R\right)}$$

where Q is the Q of the output circuit. Adjustment for peak efficiency may be somewhat critical, and the amplifier will have inefficiency due to saturation voltage and rise time, just as a class-D amplifier does. However, the simplified output circuit (compared to multiple tuning) and reduced driving problems (compared to class-D) may be worth it, especially at vhf.

summary

In this article I have tried to give an overview of high-efficiency amplifiers, particularly class-D amplifiers, which might be useful to amateurs. There are a lot of variations beyond those mentioned here. Understanding how they work requires careful attention to voltage and current relationships and a little algebra. With a little luck, an enterprising amateur should be able to implement some of these ideas into his own equipment. I would like to hear from anyone who does.

I would like to thank my friends Rich Grimsley, WA3JEL, and Bob Calderwood, WA7ANT, for their very helpful comments on the rough draft of this manuscript.

references

1. Leonard R. Kahn, "Single Sideband Transmission by Envelope Elimination and Restoration," *IRE Proceedings*, July, 1952, page 803.
2. William I. Orr, W6SAI, "The Envelope Elimination and Restoration Transmission System for SSB, *CQ*, October, 1972, page 14.
3. Robert F. Chase, "Design Aspects of Transistor Power Amplifiers," *Journal of the Audio Engineering Society*, July, 1962, page 232.
4. Donald E. Lancaster, "Amplification Using Switching Techniques," *Electronics World*, February, 1966, page 30.
5. Peter A. Stark, "Class-D for Efficiency," *Audio*, part I, June, 1964, page 23, part II, July, 1964, page 24; part III, August, 1964, page 23.
6. J.D. Martin, "Class-BD Amplifier Circuit, *Electronic Letters*, December, 1970, page 839.
7. "555 Timers," Signetics Application Note, 1973, page 23.
8. W.V. Subbarao, "Boost Audio Amplifier Efficiencies," *Electronic Design*, April 12, 1974, page 96.
9. Jacob Millman, and Herbert Taub, *Pulse, Digital, and Switching Waveforms*, McGraw Hill, New York, 1965.
10. Robert S. Olla, "Switching Regulators: The Efficient Way to Power," *Electronics*, August 16, 1973, page 91.
11. *Solid State Power Circuits: RCA Designer's Handbook*, Technical Series SP-52, RCA Solid State Division, Somerville, New Jersey, 1972.
12. D.F. Page, W.D. Hindson, and W.J. Chudobiak, "On Solid-State Class-D Systems," *IEEE Proceedings*, April, 1965, page 423.
13. F.H. Raab, "Radio-Frequency Pulsewidth Modulation," *IEEE Transactions on Communications*, August, 1973, page 958.
14. Peter Senak, Jr., "Amplitude Modulation of the Switched-Mode Tuned Power Amplifier," *IEEE Proceedings*, October, 1965, page 1658.
15. Frank Davis, "Matching Network Designs With Computer Solutions," Applications Note AN-267, Motorola, Inc., Phoenix, Arizona.
16. Herbert L. Krauss, Charles W. Allen, "Designing Toroidal Transformers to Optimize Wideband Performance," *Electronics*, August 16, 1973, page 113.
17. Octavius Pitzalis, Jr., Thomas Course, "Broadband Transformer Design for RF Transistor Power Amplifiers," *Proceedings of the IEEE Electronic Components Conference*, 1968, page 207.
18. Eugene F. Sartori, "Hybrid Transformers," *IEEE Transactions on Parts, Materials, and Packaging*, September, 1968, page 59.
19. Thomas M. Scott, "Tuned Power Amplifiers," *IEEE Transactions on Circuit Theory*, June, 1965, page 206.
20. V.O. Stokes, *Radio Transmitters: RF Power Amplification*, Van Nostrand Reinhold Company, London, 1970.
21. Warren B. Bruene, "Distortion Reducing Means for Single Sideband Transmitters," *IRE Proceedings*, December, 1956, page 1760.
22. V.J. Tyler, "A New High-Efficiency Power Amplifier," *Marconi Review*, Third Quarter, 1958.
23. David M. Snider, "A Theoretical Analysis and Experimental Confirmation of the Optimally-Loaded and Overdriven RF Power Amplifier," *IEEE Transactions of Electron Devices*, December, 1967, page 851.
24. Deiter R. Lohrman, "Amplifier Has 85% Efficiency," *Electronic Design*, March 1, 1966, page 38.
25. N.A. Sokal, A.D. Sokal, "A New Class of High-Efficiency Tuned Single-Ended Switching Power Amplifiers: I. Basic Concepts and Review of Prior Art; II. The New Class," to be published in the *IEEE Journal of Solid State Circuits*.

ham radio

feed system

for log-periodic antennas

How to find the optimum point for feeding a multi-band log periodic

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Log-periodic antenna texts provide little information on methods of getting a practical transmission line matched to the antenna feedpoint. References 2, 5 and 7 describe methods of matching and feeding vhf log periodics by use of boom balun to coax matches, but most of these systems are not suitable for high-frequency log periodics.

The original log-periodic antennas built here[9] were first fed by using a 1:1 balun with the balanced winding across the normal short-element feedpoint. Although the swr was relatively low across the 20-meter band and not too bad on 15, there was some variation between these two bands. On 10 meters there were some bad swr excursions when going from 28.0 to 29.7 MHz, some exceeding 2.5:1, showing a bad mismatch on these higher frequencies. Equipment was not readily available to make a complete swr run over the antenna's entire bandwidth, 14 to 30 MHz.

Though some of the vhf references [1,2,3,etc.] indicate that the swr could be expected to go up to 2.5:1 over a log periodic's bandwidth, it was felt this could be improved by a better matching system between the transmission line and the antenna. Upon checking several log periodics at the normal short-element feedpoint using the Omega Antenna

Noise Bridge, it was noted that there was considerable variation in impedance over the three bands.

analysis

Upon anaylzing this result it became evident that the active or driven elements (one-half wavelength long at a specific frequency) were at various electrical distances (1/4 wave-wise) from the feedpoint. In **fig. 1** for example, the second element, which is the driven element on 20 meters, is 35 feet (10.7 meters) or approximately a half wavelength to the rear of the feedpoint at the front of the antenna. Since previous tests with the antenna bridge had indicated the driven element exhibited 30 to 33 ohms input impedance, it can be assumed that this impedance would be repeated at the feedpoint since the two are connected with a feedline which is a half-wavelength long. This was confirmed by tests with the bridge on 20 meters.

Consider the situation on 15 meters. Element 6 is a half-wavelength long on that band so it becomes the active or driven element. It is located about 16.5 feet (5.1 meters) from the feedpoint, but a quarter-wave of open-wire feedline on 15 is about 11.25 feet (3.4 meters) and a half-wave about twice that long (22.5 feet or 6.9 meters). Thus, the feedpoint is about halfway between a high- and low-impedance point on 15 meters.

Looking at 10 meters, element 9 is about 16 feet (5 meters) long so it is the active element on that band. It is about 6.5 feet (2 meters) to the rear of the feedpoint. A quarter-wavelength feedline on 10 meters is about 8.4 feet (2.6 meters) and a half wave, 16.8 feet (5.2

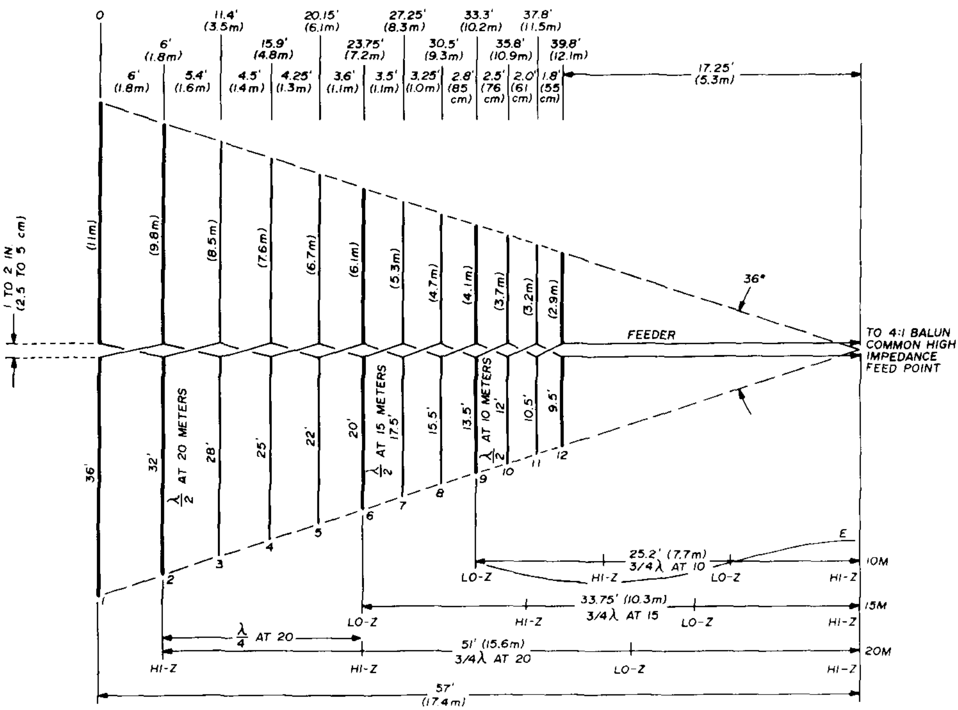


fig. 1. A 12-element three-band log-periodic antenna showing the electrical relationship of the extended feedpoint to the driven element on each of the three bands.

meters). Again, the feedpoint is at an intermediate point with respect to the active element.

In summary, it will be noted that although the feedpoint at element 12 presents a fairly predictable impedance on 20 meters, it presents a highly variable match on 15 and 10. This was confirmed by swr readings across each of the three bands.

moving the feedpoint

By extending the open-wire feedline toward the antenna apex as shown in **fig. 1**, a point is reached near the apex where elements 2, 6 and 9 are all about 3/4 wavelength from this common, higher impedance, feedpoint for their respective bands. The impedance at this point appears to be on the order of 200 to 300 ohms, so it can be fed with 50-ohm coax through a 4:1 balun with a satisfactory match on all three bands. The 3/4-wavelength open-wire line acts as a matching transformer.

The low and high impedance points along the open-wire line for each of the three bands are shown in **fig. 1**. Incorporation of this modification extends the feedpoint 17.25 feet (5.3 meters) forward of the short-element end of the antenna.

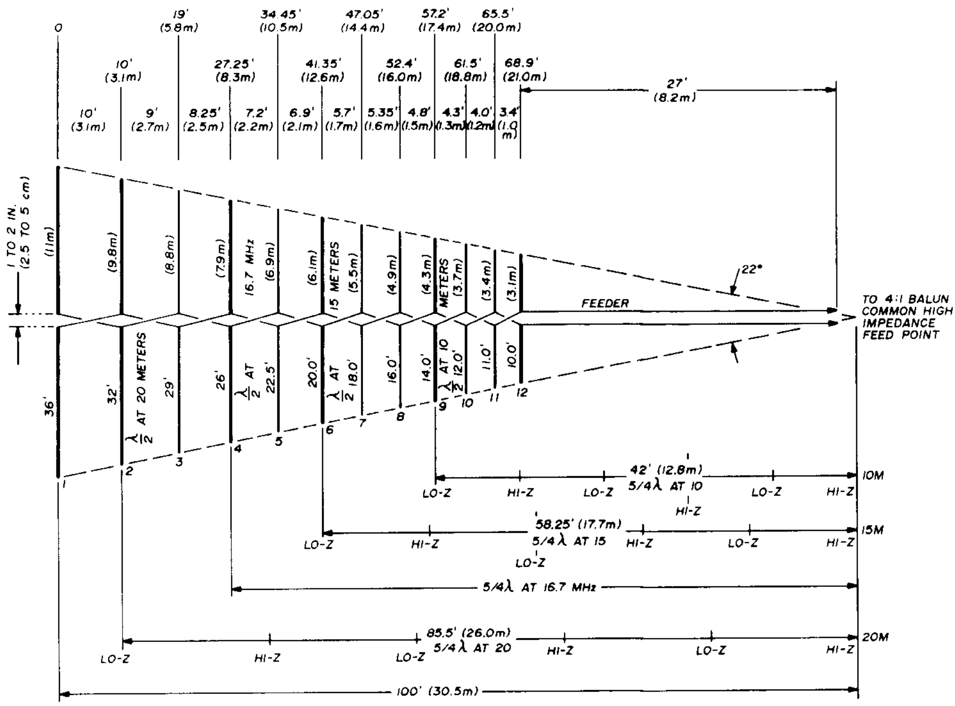


fig. 2. An extended 12-element three-band log periodic with a 5/8-wavelength extended-feed matching system.

In **fig. 2** the same principle of an extended open-wire feeder is applied to matching a longer log periodic with a 70-foot (21.4-meter) boom length and 22-degree apex angle. This requires an open-wire feeder 5/8-wavelength long to reach the common-impedance feedpoint, also approximately at the apex angle. In this case the open-wire feeder has been extended 27 feet (8.2 meters) from the center of the short element. Note that these extended feeders can hang down from the short-element end of the antenna if necessary; they need not be extended horizontally as shown.

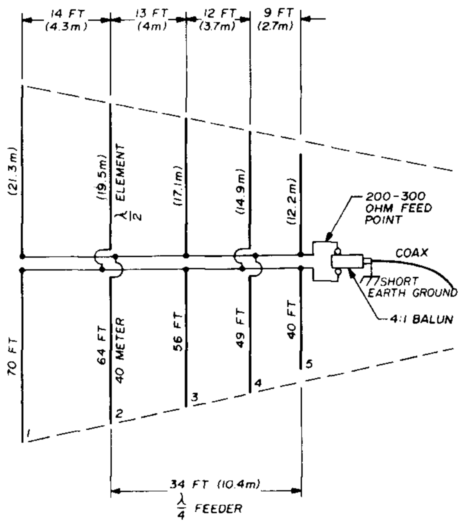


fig. 3. A 5-element, 40-meter monoband log periodic. The center of the short element is just a quarter wavelength from the driven element, providing an optimum feed point.

The longest 20-, 15-, and 10-meter log periodic in use here (17 elements, with a 100-foot (30.5-meter) boom and 16 degree apex angle) requires seven quarter-wavelengths between each active element and the common feedpoint.[14] Further, it will be noted that any active element on any of the antennas shown is an odd number of quarter wavelengths, three in **fig. 1** or five in **fig. 2**, from the common feedpoint. For example, element 4 in **fig. 2** is 28 feet (8.5 meters) long and will resonate at 16.7 MHz. It is approximately 5/4-wavelength from the common feedpoint at this frequency, so we can therefore assume that this antenna is a true log periodic.

The monoband log periodics of **fig. 3**, tested here on 10, 15, 20 and 40 meters in 5-element versions (some 4- and 6-element types were also tested) have all had element 2 exactly a quarter wavelength from the high-impedance, short-element feedpoint. These have worked extremely well using a 4:1 balun to match them to coaxial transmission lines. The swr has been relatively low across each band.

Similarly, the single-band vertical monopole log periodics of **fig. 4**, tested on 40 and 80, also used the quarter-wavelength feed and were similarly flat.[15] The swr readings on the 80-meter version were:

4.0 MHz	1.25:1
3.9 MHz	1.4:1
3.8 MHz	1.2:1
3.7 MHz	1.1:1
3.6 MHz	1.2:1
3.5 MHz	1.2:1

similar approach

This system for feeding log-periodic antennas was believed to be original at

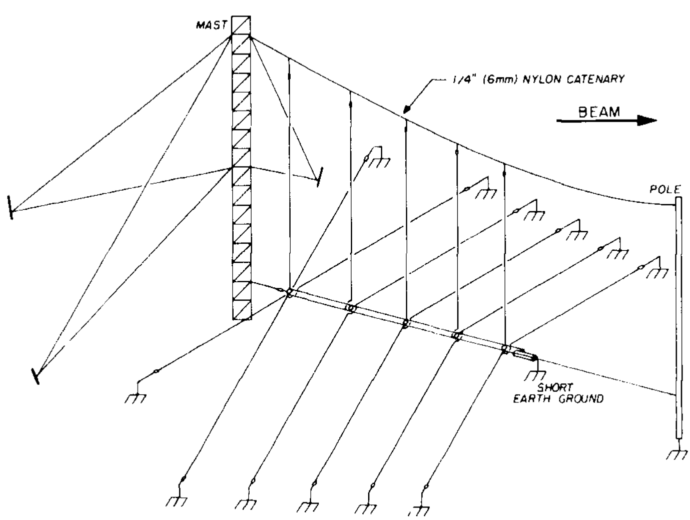


fig. 4. Overall view of the five-element vertical monopole log periodic. Construction details and dimensions are shown in fig. 5 and table 1.

table 1. Vertical monopole log-periodic antenna dimensions (5-element arrays).

	frequency in MHz			
element	3.5-4.0[1]	3.8-4.0[2]	7.0-7.3[2]	14.0-14.35[1]
E1	70' (21.4 m)	65' (19.8 m)	35' (10.7 m)	17.5' (5.3 m)
E2	67' (20.4 m)	62' (18.9 m)	33' (10.0 m)	16.5' (5.0 m)
E3	58' (17.7 m)	55' (16.8 m)	28' (8.5 m)	14.0' (4.3 m)
E4	50' (15.3 m)	45' (13.7 m)	24.5' (7.5 m)	12.2' (3.7 m)
E5	43' (13.1 m)	40' (12.2 m)	20' (6.1 m)	10.0' (3.0 m)
S1	30' (9.2 m)	26' (7.9 m)	14' (4.3 m)	7.0' (2.1 m)
S2	27' (8.2 m)	24' (7.3 m)	13' (4.0 m)	6.5' (2.0 m)
S3	24' (7.3 m)	23' (7.0 m)	12' (3.7 m)	6.0' (1.8 m)
S4	19' (5.8 m)	18' (5.5 m)	9' (2.7 m)	4.5' (1.4 m)
total length	100' (30.5 m)	91' (27.8 m)	48' (14.6 m)	24' (7.3 m)
mast height	80' (24.4 m)	75' (22.9 m)	50' (15.3 m)	30' (9.2 m)
pole height	45' (13.7 m)	40' (12.2 m)	25' (7.6 m)	20' (6.1 m)

1. Calculated design, not actually built and tested.
2. Built and tested design, with measured swr under 1.5:1 over frequency range shown.

the time I worked it out. However, after it was mentioned briefly in a previous article[9] it was learned that Ray Rosenberry, K8EBF, developed a similar method that was described and covered by his patent of 16 February, 1971, which covers "Broad Band Transformer Antenna and Related Feed System."[13] Therefore, I do not claim the odd quarter-wavelength feed method for log periodics to be original. K8EBF and I have since exchanged several letters regarding these log-periodic feed methods.

In any case, it is hoped the above information on improved methods of feeding log-periodic antennas will be helpful to amateurs using these interesting antennas. I would like to hear from anyone trying this technique.

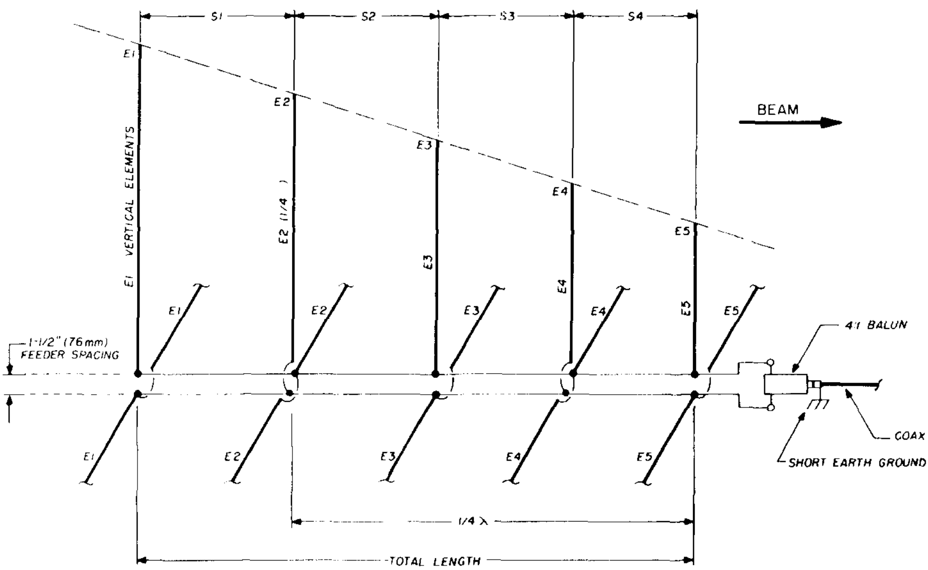


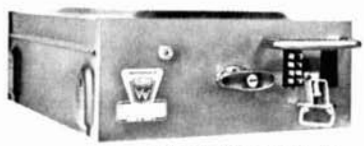
fig. 5. Construction details for a 5-element vertical monopole log periodic. Dimensions for 80, 75, 40 and 20 meters are given in table 1.

references

1. Carl T. Milner, W1FVY, "Log Periodic Antennas," *QST*, November, 1959, page 11.
2. Robert F. Heslin, K7RTY, "Three-Band Log Periodic Antenna," *QST*, June, 1963, page 50.
3. A.E. Blick, VE3AHV, "A Wide-Band High Gain Antenna," *73*, November, 1964, page 6.
4. A.E. Blick, VE3AHV, "The Design of Log Periodic Antennas," *73*, May, 1965, page 62.
5. Hal Greenlee, K4GYO, "VHF Log Periodics and the Log-Scan 420," *73*, October, 1967, page 40.
6. Paul H. Lee, W3JM, "Vertical Antennas (Part VII)," *CQ*, December, 1968, page 59.
7. William T. Nagle, W3DUQ, "Log-Periodic Antenna Designs for UHF/VHF," *73*, August, 1970, page 45.
8. G.E. Smith, W4AEO, "Three-Band HF Log-Periodic Antennas," *ham radio*, September, 1972, page 28.
9. G.E. Smith, W4AEO, "40-Meter Log-Periodic Antennas," *ham radio*, May, 1973, page 16.
10. H. Jasik, "Log Periodic Design," *Antenna Engineering Handbook*, McGraw-Hill, New York 1961.
11. R. Carrell, "Analysis and Design of the Log Periodic Dipole Antenna," *IRE National Convention Record*, McGraw-Hill, New York 1961.
12. Defense Communications Agency, "MF/HF Communications Antennas," *Engineering Installation Standards Manual*, DCAC 330-175-Addenda No. 1, 1966.
13. Ray A. Rosenberry, K8EBF, "Broad Band Transformer Antenna and Related Feed System," U.S. Patent 3,564,555, 1971.
14. G.E. Smith, W4AEO, "High-Gain Log Periodic for 10, 15 and 20," *ham radio*, August, 1973, page 18.
15. G.E. Smith, W4AEO, "Vertical Monopole Log Periodic Antenna for 40 and 80 Meters," *ham radio*, September, 1973, page 44.
16. Peter Rhodes, K4EWG, "The Log-Periodic Dipole Array," *QST*, November, 1973, page 16.
17. G.E. Smith, W4AEO, "Fixed Log-Periodic Beam for 15 and 20 Meters," *ham radio*, May, 1974, page 6.

ham radio

"Ever since I bought that $450 receiver, I've had a communication problem — my XYL!"



high-stability crystal oscillator

The Goral oscillator — a new high-performance crystal-oscillator circuit that features excellent load capacitance correlation and temperature stability

Donald L. Stoner, W6TNS, Director of Marketing, SGC, Inc.*

One of the most frustrating problems faced by a newcomer to the crystal manufacturing business is that of capacitance correlation of the oscillators. Although 32 pF has been the recommended standard for many years, few engineers seem inclined to use this value in their new circuits. In many cases the engineer gets the circuit working to his satisfaction and is reluctant to change any of the component values. Usually, the burden of correlation falls on the crystal supplier.

A second problem, which is no less irritating, is that of activity requirements. The crystal vendor may supply perfectly good crystals, only to find that many will not oscillate in the user's circuit.

While the crystal oscillator circuit to be described will not cure any of these past problems, it can certainly minimize them in the future. Although the oscillator configuration (which is an adaption of the basic Colpitts circuit) may not be new, I am unaware of any similar designs. It was developed independently in the quartz crystal laboratory at SGC, Inc., and has the following features:

1. The ability to correlate at virtually any capacitance between 5 and 50 pF. In fact, the crystal will oscillate very close to its series-resonance point in this circuit.

2. The ability to make crystals oscillate with equivalent series resistances (ESR) well above the Mil-spec maximum. The circuit is sufficiently active to oscillate quartz blanks which have not been plated during the manufacturing process.

3. The temperature stability is essentially independent of the solid-state devices used. Capacitance variations due to the semiconductor junctions are virtually swamped out due to the large shunt capacitance in the circuit.

4. The circuit is easily adapted to "rubber" the crystal with semiconductor variable-capacitance diodes and exhibits a very wide pulling range due to its high activity.

Colpitts oscillator

The simplified circuit for the transistorized Colpitts oscillator is shown in **fig. 1**. Note that the rf ground has been shifted from the customary position at the collector. Oscillation occurs due to the 180° phase-shift through the transistor and the additional 180° inversion across the tuned circuit represented by the crystal. The capacitor values are determined by the circuit impedance and frequency range.

The basic circuit for the fet Colpitts oscillator is quite similar and is shown in **fig. 2**. Note that the rf ground has been moved to its customary position by bypassing the source (collector), leaving the drain (emitter) at an rf potential above

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ground. Thus, one end of all crystals in a bandswitching circuit can be grounded. The fet Colpitts circuit is also very useful because the temperature characteristics are excellent. The fet causes virtually no drift with temperature.

Fig. 3 shows a practical application for the fet Colpitts oscillator. The values have been optimized for the 10-to-20-MHz range. Note that this circuit also incorporates a leveling diode, CR1, that rectifies the rf voltage across the crystal. Thus, the more active the crystal, the more negative bias which is produced. This, in turn, reduces the gain of the oscillator. Thus high and low activity crystals tend to produce the same output voltage at the drain of the fet.

Unfortunately, the fet Colpitts is not a particularly active circuit and seems to require lower resistance crystals than its transistor counterpart. Crystals with an ESR above 20 ohms appear to be quite

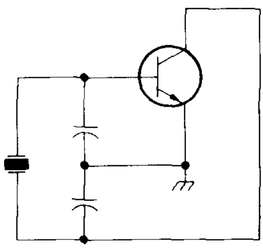

fig. 1. Basic Colpitts oscillator using an npn transistor.

sluggish. In this instance, the ESR referred to is measured at parallel resonance. This is the mode the crystals oscillate on in this circuit.

The sluggishness of the fet circuit is due primarily to the shunt loading placed across the crystal by the netting capacitor, C1, and the diode, CR1. If a variable-capacitance diode is used in the circuit (in addition to the netting capacitor), crystals with ESRs of less than 16 ohms are required for reliable starting.

Goral oscillator

Obviously, it is possible to make the basic fet Colpitts oscillator more active by operating it at higher drive levels. However, for best stability, the crystal drive level should be kept as low as possible, consistent with reliable starting. If the oscillator loop gain can be increased without increasing crystal current or substantially increasing drive level, the performance of

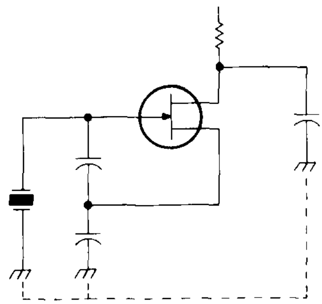

fig. 2. Basic Colpitts oscillator circuit using an fet.

the basic Colpitts fet oscillator can be noticeably improved.

This is what is done in the Goral oscillator circuit shown in **fig. 4**. While only a few components are added to the basic circuit of **fig. 3**, and the circuit changes are subtle, the difference in performance is extraordinary. Again, the component values are optimized for 10 to 20 MHz. In this circuit transistor Q2 acts as an emitter follower to provide power gain for the feedback energy without changing the phase angle of the signal. The increased feedback permits increased values of C2 and C3 from those shown in **fig. 3**. This further increases the tempera-

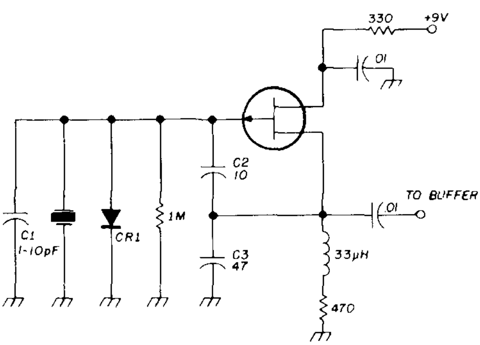

fig. 3. Practical Colpitts oscillator using an fet. Component values have been optimized for the 10- to 20-MHz frequency range.

ture stability of the circuit. Transistor Q3 is a simple buffer to prevent oscillator loading.

Don't be concerned by the strange numbers associated with the transistors. Device Q1 is a Motorola jfet and was selected because of its low cost ($.38 each). Practically any junction-type field-

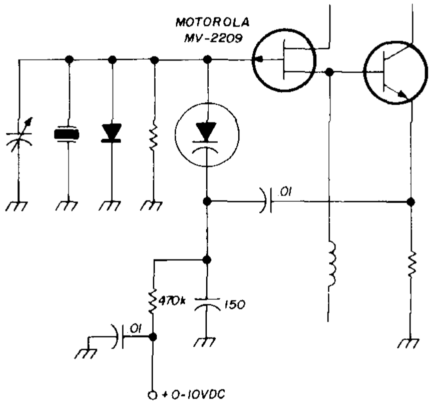

fig. 5. A varicap may be used in the Goral oscillator, as shown here, to vary the output frequency from a variable dc source.

effect transistor will work in the circuit without affecting performance. The MPS-5172 may also be an unusual number. Again, it is the lowest cost Motorola rf small-signal device in their line ($.21 each). There are HEP equivalents, but, frankly, they are more expensive because

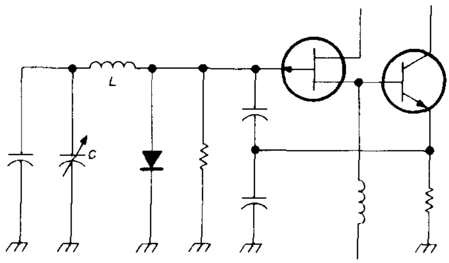

fig. 6. Using the Goral oscillator as a highly stable vfo. The L/C values are chosen for the desired output frequency.

of the packaging. Again, transistors Q2 and Q3 are totally non-critical and virtually any general purpose npn rf type should work equally well. The agc diode, CR1, is a 1N914 or 1N4148.

Fig. 5 shows a simple variation to the basic Goral oscillator which incorporates a variable-capacitance diode. This allows the frequency to be varied with an external dc source (such as a clarifier on fixed-frequency ssb equipment) or modulated for fm applications.

Although the circuit of **fig. 6** is untested, it should make an outstanding vfo. Any temperature instability and drift which occurs in this circuit is the result of the tank circuit and not the devices or components.

A printed-circuit board for a simple crystal test oscillator is shown in **fig. 7.** Note the only variation from **fig. 4** is the

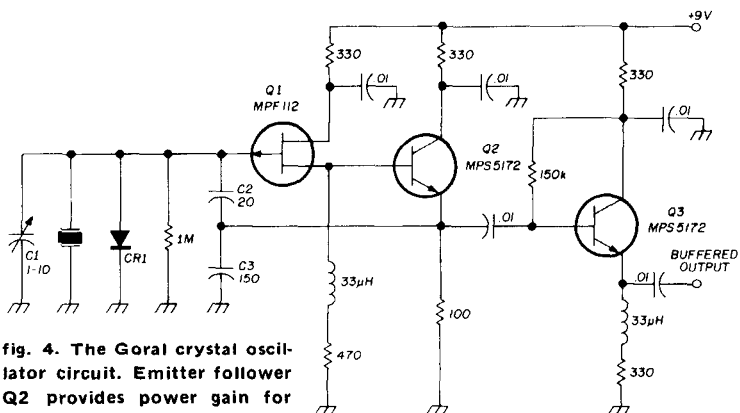

fig. 4. The Goral crystal oscillator circuit. Emitter follower Q2 provides power gain for the feedback energy, providing high crystal activity without affecting the crystal drive level. Transistor Q3 is the output buffer. Diode CR1 is a 1N914 or 1N4148.

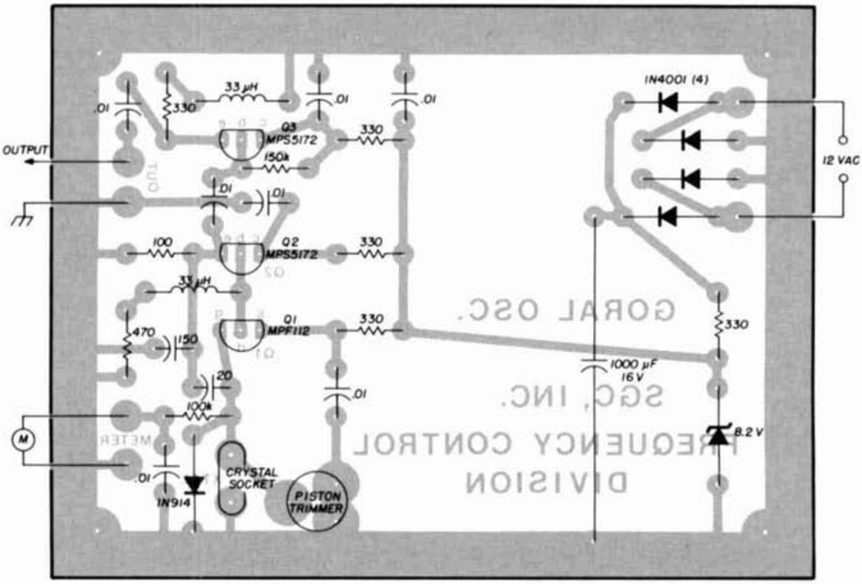

fig. 7. Printed-circuit component layout for a simple crystal test set using the Goral oscillator. This same circuit board may be used for the circuit shown in fig. 4 (see text). Full-size PC board is shown in fig. 8.

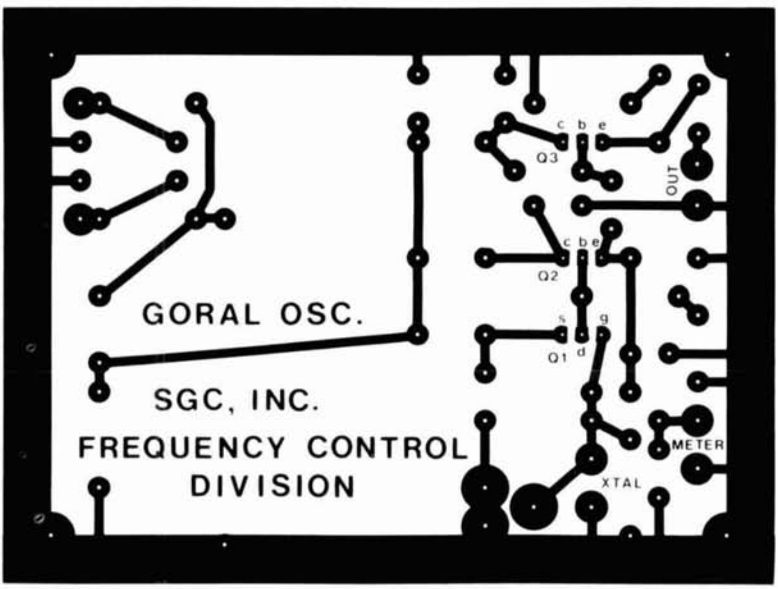

fig. 8. Full-size printed circuit board for a simple crystal tester.

value of the gate resistor for Q1. Here it is reduced to 100k to permit reading the gate current (and, therefore, crystal activity) on the meter.

I wish to thank Pierre Goral, who developed the circuit, for his assistance in preparing this article.

ham radio

simple

tunable receiver modification for vhf fm

Simple vfo adds all-channel receiving capability to two-meter fm transceivers

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Vhf fm transceivers have become very popular for local communication, taking much pressure off the high-frequency bands, but the typical fm transceiver, with its limited number of channels, lacks the versatility that many hams desire. In Southern California, for example, every two-meter channel is occupied – some many times over – and trying to provide operating capability on each can be very expensive, whether the approach taken is multiple crystals or a frequency synthesizer. Yet most hams would like to operate, or at least have the capability to operate, on many channels. After operating for a while, mostly mobile, on a few channels that were already installed in the used rig I bought, I came to the conclusion that what I really needed was tunable receiving capability, not vast numbers of full channels. A tunable receiver permits me to listen in on other channels, perhaps finding one I'd like to try, or quickly eliminating others because of the geographical coverage, use of the repeater, or even the people on the channel. It's obvious, I believe, that some repeaters welcome new blood, whereas others are occupied by users who prefer to talk to the same people, just as is true in any social organization.

A tunable receiver also permits tuning the input of repeaters when malicious or accidental interference disrupts the frequency, making a little transmitter hunting desirable.

I developed the simple variable-frequency oscillator shown in **fig. 1** to give me the tunable receiving capability needed for the relevant upper two megahertz of the two-meter band. It replaces the first crystal oscillator in an fm transceiver, and tunes over the required range, generally one-third of the first injection frequency; i.e., it operates at approximately 45 MHz for popular fm transceivers, a frequency that can easily be changed if needed.

The vfo can either be built into an existing transmitter, or into an add-on enclosure. The circuit itself is very small, and the potentiometer used to tune it can be placed remotely.

circuit description

The vfo uses a field-effect-transistor oscillator tuned by a tuning diode (variously known as a Varicap, varactor or variable-capacitance diode). A source-follower output stage buffers the oscillator, and the supply voltage is regulated by a zener diode. Stability is certainly adequate for the usual fm receiver, but I haven't checked it on one with a very narrow bandpass.

None of the parts in the vfo seem exotic, and it should be possible for any active building ham to put it together in a few hours out of parts in his collection.

The oscillator uses an inexpensive plastic field-effect transistor in a Colpitts circuit. The transistor is a member of the popular and large Motorola family whose Grandfather is the MPF102, but I recommend that you use one of the better specified versions rather than the MPF102, which has a very wide I_{DSS} range. I used the MPF102, but ended up having to try different values of source resistance to get satisfactory results.

The oscillator tank coil is a simple four-turn coil of heavy silver-plated wire. The silver is obviously not needed, but I found it easier to unwind a short piece of World War II vintage tank-transmitter coil than find tinned number-16 copper wire. A toroidal coil would also be suitable,

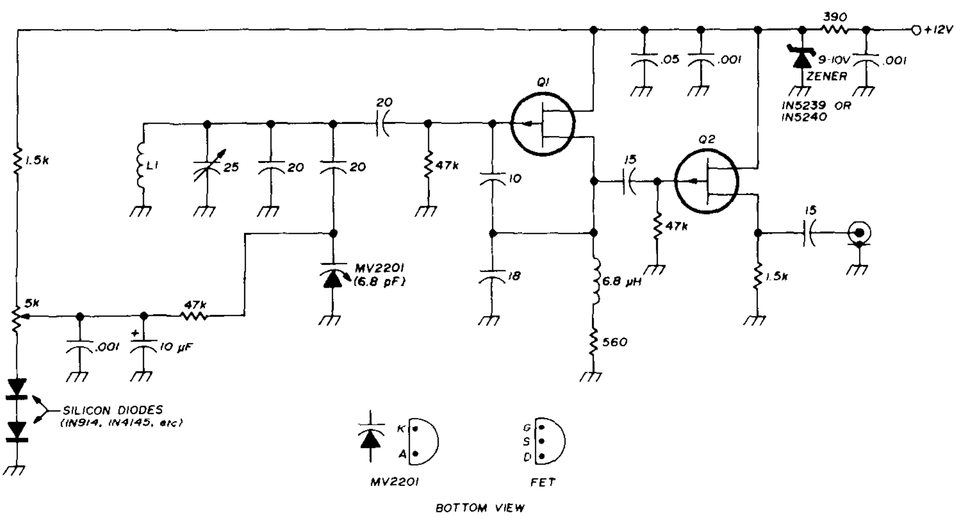

fig. 1. Schematic diagram of the receiving vfo for two-meter vhf-fm equipment. Fets Q1 and Q2 are MPF102 types (2N5668, 2N5669 are better). L1 is 4 turns no. 16, ½" (13 mm) in diameter.

perhaps even necessary, for lower-frequency versions if you want to keep the vfo small.

The circuit is tuned by an inexpensive Motorola tuning diode in a plastic TO-92, D-shaped case like that used for the fet oscillator. The particular diode used, the MV2201, has a nominal capacitance of 6.8 picofarads, but any similar diode — even an expensive military type — is suitable. I used Motorola parts because they are widely available; the HEP versions are quite suitable with the sole warning that their HEP802 fet appears to be like the MPF102, so the same warning about the source resistor applies. If it doesn't work, try another value of resistance.

The varactor tuning makes it simple to tune the unit remotely, and to pick restricted ranges, but a small trimmer capacitor could also be used. In this case, construction is more complicated and critical.

With a variable resistor for tuning, however, you can take a number of approaches. A simple 270° potentiometer will cover the band in one swing, but makes tuning a little tricky. One is easy to add to the front panel of a transceiver, however, and if the tuning range is restricted to part of the band, this should work. Use a composition pot, not a wirewound one, which tends to give step-wise tuning, and the steps aren't likely to be the ones you want.

For best control and calibration, I recommend a ten-turn potentiometer and appropriate digital dial. With a 2000-kHz range, and close to 1000 divisions, repeatability and calibration is excellent. It won't be linear calibration, of course, though if you're a masochist, you could probably come close with proper selection of component values and padding. A wire-wound pot is fine for this use since the steps are much smaller.

It's also possible to use a switch and multiple resistive trimming pots for selecting specific channels. I still recommend that you have provision for variable tuning, however.

You might notice the two diodes at the ground end of the potentiometer. These forward-biased silicon diodes raise the cold end of the pot about 1.4 volts above ground, ensuring that the varactor is reverse biased at any setting of the pot. They also help select the proper bandspread (with the 1500-ohm resistor and 5000-ohm pot), and provide some temperature compensation for the varactor, at least in theory. I don't have the facilities for checking the latter, and am not ambitious or curious enough to find them.

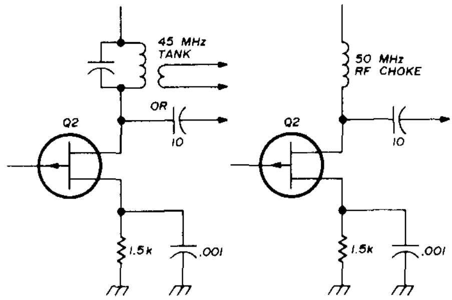

fig. 2. Suggested tuned circuits for obtaining higher output drive from the buffer stage.

I highly recommend that you use quality mica capacitors in the frequency-determining tank circuit (and that includes all small value capacitors in the circuit except the 15-pF output capacitor). An unstable ceramic capacitor can be very frustrating, particularly if you use the unit in an unheated garage or automobile (admittedly not as big a problem in coastal Southern California as it is in Wisconsin or New Hampshire). The small rf choke, by the way, is not critical in value. The circuit works without it, but exhibits considerable amplitude variation across the tuning range.

The buffer output stage is straightforward, and uses the same type of transistor as the oscillator. The source follower configuration provides adequate drive for popular transistor rigs; if drive is inadequate, it might be necessary to convert this stage to a tuned-drain version, as shown in **fig. 2** (I haven't tried this, though). Even a broadly tuned rf choke might be adequate, but don't bother unless you try. Most quality rigs designed for fm don't require much drive; it would make the crystals drift. A converted military receiver might be another matter.

The vfo operates from about 12 volts, with a 9- or 10-volt zener diode regulating the voltage to the transistors and tuning diode. Little current is required, but if you operate from small batteries, you can dispense with the zener and operate directly from 9 volts or so. The short-term variations should be small enough for the intended use. That's not true in a car, however. The supply voltage there often varies from 11.5 to 14.5 volts.

construction

The easiest way to make the vfo is probably to use a small peice of perforated Vector board. An etched circuit board is prettier, but a lot of trouble if you're just making one. Do mount everything solidly, as in any vfo. I found fairly extensive filtering and shielding necessary, but this might not be critical out in the provinces. Before I shielded the unit, it received amateurs, Adam 12, aircraft and Alice Cooper, simultaneously. A shielded cable is vital for both remote control and output leads, also.

installation

The electrical installation is relatively straightforward; I'll leave the mechanical engineering to you. Simply unplug one crystal, and connect the output of the vfo to the hot end. In the Tempo FMP I use, the high end of the crystal is switched, and the low end is grounded through a small trimmer capacitor. Make sure that you connect the vfo and cable ground directly to the transceiver ground, not through this trimmer. Use the shortest lead possible, and a direct ground.

I recommend Teflon-insulated miniature cable, not RG-174/U with its soft plastic insulation. Most of the fm rigs are tiny, and burning plastic insulation looks and smells horrible. By the way, the battery compartment of my Tempo FMP has space for the vfo.

One warning: It is possible for the crystal oscillator in the rig to take off when you attach the input lead to it, but this can be prevented by installing a small rf choke in the lead from the vfo right at the crystal socket. A couple of small ferrite beads may do the job. If worst comes to worst, you might even have to ground the emitter of the crystal oscillator transistor through a bypass capacitor of, say, 470 pF, when using the tunable vfo. I didn't have any trouble with one vfo I built, but the other needed the rf choke.

calibration

I suggest that you make sure the vfo is working properly before you install it, as the installation will undoubtably be a little tedious if you put it in a transceiver. The easiest way to check operation and range is with a suitable frequency counter. You can also use a monitor receiver, or a signal generator plus the receiver, but these can be confusing due to the numerous images possible. You'll need to touch up the tuning after installation. If the tuning range isn't correct, you can juggle component values. This technique is undoubtably all too familiar to anyone who reads *ham radio* and has read this far.

final note

Just out of curiosity, I replaced the source-follower output stage with a tuned tank circuit on two meters (as in **fig. 2**), then introduced a small amount of audio into the varactor from a dynamic microphone. The combination transmitted good quality fm for a few blocks, but I can't really recommend the technique for general use, not with the sharp receivers (and tongues) found in most areas. I don't even recommend it as a crystal replacement for transmitters for the same reasons.

ham radio

mechanical design of cubical quad antennas

Construction notes for a quad designed to withstand the fury of Canadian winters

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After using a Yagi antenna for ten years with excellent results, the time came when it had to be replaced. I decided this was a good time to test the relative merits of the quad antenna. The following piece presents the results of four years of work dealing with construction problems of a *cubical quad in a Canadian climate.* Emphasis is placed on mechanical details such as clips and fasteners, joint interfaces, protection of wire elements and spreader design. On-the-air results are also reported, which are based on qualitative observations.

Electrically, the design is the same as that described by Lee Bergren in the May, 1963, issue of *QST*.[1] The only claim I have to this design is the mechanical features described here.

project objectives

The quad has a bad reputation in Canada because of mechanical problems that occur during the severe winters. My first two models failed during successive winters; the third model survived three Toronto winters with no maintenance. It *was designed with the following objectives:*

1. Stronger joints between crossarms and boom.
2. Better clamps between spreaders and wire elements.

3. A means to avoid element breakage.

4. A better joint between spreaders and crossarms.

description

The boom is made of 3-inch (7.6-cm) aluminum irrigation pipe instead of the 4-inch (10.2-cm) diameter pipe used in Bergren's design and proved to be quite satisfactory. It is lighter in weight and crossarm-to-boom joints remained tight by minimizing sway in the spreaders, which could elongate the holes in the boom. In a commercially-built quad, the holes through the boom have additional bearing surfaces provided by sleeves shrunk onto the boom. This is difficult for the amateur to achieve, so it was necessary to make a tight fit with the materials available. If you have the means to shrink sleeves onto the boom at these points, the advantage is obvious. Aluminum irrigation pipe is not always perfectly circular, and this in itself presents a difficulty when making sleeves or spider clamps.

drilling the boom

As explained in the article by Bergren, holes are drilled at 90 degrees through the boom 1/8 inch (3 mm) apart. These holes are to accommodate the square aluminum plate used as a support. Certain precautions must be observed, however, in drilling the holes to make them accommodate a push fit for the 1¼-inch (32-mm) ID aluminum tubes used for crossarms, each of which is 4 feet (1.2 meters) long.

To avoid some of the weaker points in antenna construction much care must be used in marking the boom for drilling. Nothing but utmost pains is good enough. Circumscribe on the outside of the metal boom a circle that *exactly* defines the outside contour of the tube hole. If you are using 1¼-inch (32-mm) ID tubing, the circles will be 1.376 inches (35.0 mm) diameter (for a wall thickness of 0.063 inch, or 1.5 mm). A tube with a thicker wall will need holes slightly farther apart.

When correctly marked, the holes will be drilled to a diameter of 1¼ inches (32 mm). When using a large drill through a thin-wall tube, the inside of the holes will be rough and uneven. It is essential that the holes make a perfectly smooth fit for the tubing forming the antenna cross arms.

The hole now lies about 1/32 inch (1 mm) inside the circumscribed circle. A steel plug 1.413 inches (36 mm) in diameter is now prepared. File the rough-drilled hole carefully until it is perfectly circular, so that the steel plug fits the hole exactly.

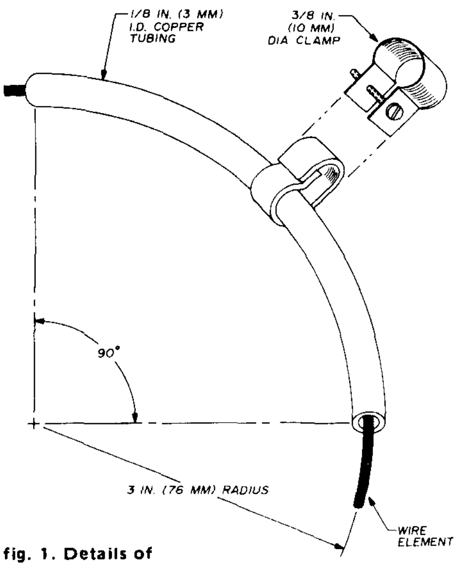
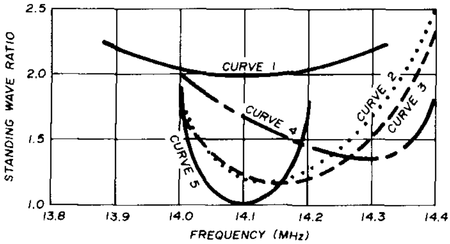


fig. 1. Details of the clamp and support for antenna elements.

measurement notes

You'll notice that dimensions for holes and parts are given quite exactly, and this is important. If the antenna is to withstand the weather, care in making measurements is imperative. Much care and patience at this point will pay off in a maintenance-free installation. It's surprising how exactly the fitting process can be done, especially if a jig or template is available.

The remaining 1/32 inch (1 mm) of the crossarm hole is now filed out, using the circumscribed circle on the metal and a piece of the crossarm tube as templates. A really tight fit is the objective here – a joint that will not work loose. The corresponding hole on the other side of the boom is similarly marked and drilled (don't try to drill straight through the boom). By careful measurement, the holes will be so closely opposed to each other that the spreader tips, when assembled, will not be more than 1 inch (25 mm) out of alignment.



Curve 1	Driven element only, 15 feet (4.6 m)
Curve 2	1st director added, 15 feet (4.6 m)
Curve 3	2nd director added, 15 feet (4.6 m)
Curve 4	Boom lifted to 30 feet (9.1 m)
Curve 5	Reflector added, 75 feet (22.9 m)

fig. 2. Standing wave ratio readings taken during assembly of the array. Bridge was located at the junction of the coaxial transmission line and the element except for curve 5, when the bridge was between the coaxial transmission line and the transmitter. Dimensions refer to boom heights above ground.

machining the boom

The only part of the work that required commercial help was turning a 24-inch (61-cm) length of aluminum tubing to join two 15-foot (4.6-meter) lengths of aluminum irrigation pipe used for the boom. The pipe arrived in two 20-foot (6.1-meter) lengths. However, the boom went together so easily, and was erected so simply, that if I did the job again, I'd have no hesitation at all in using a 40-foot (12.2-meter) boom.

If, as in my case, the pipe is not absolutely circular, carefully measure the *maximum* and minimum diameters, average them, and subtract 0.003 inch (0.1 mm) for clearance. Grease the pipe well (a good silicone grease is best), and hammer the two boom lengths onto the junction piece using a block of wood and a sledge hammer. This completes the boom except for minor details.

spreaders

Fiberglass tapered tubes are used for the spreaders, rather than aluminum, because the fiberglass causes less wind loading. The spreaders are 13 feet (3.96 meters) long, 1¼ inches (32 mm) in diameter, tapering to 3/8 inch (10 mm). This configuration presents a nicely balanced combination of adequate stiffness with light weight.

At a length of 13 feet (3.96 meters), the two spreaders in line need no separation to achieve the desired length, and so are simply moved down the 1¼-inch (32-mm) diameter crossarms until they meet at the center. They are fixed in this position by the bolts that secure each crossarm to the square plate, since these bolts pass through the aluminum tube, fiberglass tube and plate.

The only other adjustment is at the point where the spreader emerges from the crossarm. Since the spreader is tapered, some play will exist at this point. This play is taken up by inserting a neoprene O-ring just inside the end of the aluminum crossarm. It needs no holding in place, but the joint at this point can be covered by a machined aluminum sleeve, made to fit the two tubes, and secured by two self-tapping screws.

The size of the thick end of the spreader should be checked with the manufacturer before buying your crossarm material. Mine required a little work with an emery cloth to make a perfect fit.

clips and fasteners

The homemade clip shown in **fig. 1** resulted from many experiments. The *clamp is a commercially obtained item.* The tube portion, which carries the wire element, is made from 1/8-inch (3-mm) ID copper tubing. The tube radius should be 3 inches (76 mm). Sections of the copper tube are cut off so that the ends point at right angles to each other. The supporting band, to which the 3/8-inch (10-mm) diameter clamp attaches, is a strip of copper cut to length, formed, and soldered to the copper tube as shown. The idea is to provide support to the wire elements through the entire radius of the bend, presenting no solid point where the wire could fracture from vibration.

When the wire loops have been fed through the tubing clamps, cut to length, and secured, the wire will be prevented from slipping through the clamps by solder dropped onto the wire just clear of the clamp ends. One or two turns of number-22 AWG (0.6-mm) wire at the desired point will assist in making a good solder joint. Note that cold solder jobs in this area are a definite "no-no" if your antenna is to withstand the elements.

Be certain the wire elements move freely within the copper tubing. Any sharp bends in the wire will defeat the entire idea of this project; remember, care in construction will pay off in maintenance-free operation.

rotator

The usual pressure-grip clamp arrangements used on the antenna rotator shaft (2 inches, or 51 mm) diameter are inadequate for an antenna of this size. If a HAM-M rotator is used, the ¼-inch (6-mm) bolt that screws into the rotating shaft at top and bottom of the motor should be removed. This bolt should be replaced with a 3/8-inch (10-mm) high-tensile-strength bolt to avoid shearing under the stress involved.

performance

The curves in **fig. 2** show the standing wave ratio of the antenna during assembly. Curve 5 shows swr with the complete array elevated to 75 feet (22.9 meters). Antenna bandwidth is 200 kHz with an swr of less than 2:1, which is to be expected. Qualitative tests indicated a front-to-back ratio of 28 dB. Not bad for a home-built antenna.

reference

1. Lee Bergren, WØAIW, "The Multielement Quad," *QST*, May, 1963, page 11.

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More Details? CHECK—OFF Page 94

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H

automatic reset timer

Using the versatile NE555 timer IC as a ten-minute ID timer or repeater time-out timer

Harvey Vordenbaum, W5ZHV, 5446 South Shady Creek, Houston, Texas 77017

Recently, when a friend expressed a need for a timer with automatic reset or triggering capability, the NE555V integrated circuit came to mind. The NE555V is a versatile, inexpensive IC designed especially for timer and oscillator use. External components determine the time delay or oscillator frequency and duty cycle. The output is capable of sourcing or sinking 200 mA, adequate for most small relays.† Other basic timer circuits have been described previously,[1,2] but all require triggering by a manually-operated switch or by relay contacts.

†Although a relay coil is shown as the load, the NE555V may be able to operate some loads directly. The 200-mA load current is for a supply voltage of 15 volts, however, and load current will be less for lower supply voltages.

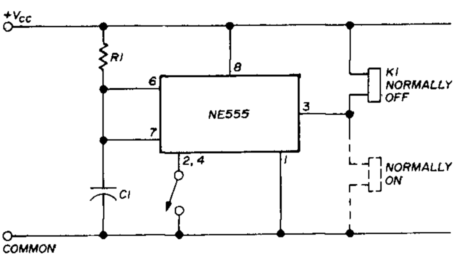

fig. 1. Basic timer circuit uses NE555 IC. Time delay is set by RC product of R1 and C1.

Fig. 1 shows the basic timer circuit. As shown, the relay or other load is normally *off.* For normally *on* operation connect the relay or other load between pin 3 and ground. The delay time constant is set by the simple RC product of R1 and C1. Pins 2 and 4 are grounded momentarily through switch S1, providing start or manual reset of the timer. Pin 2 is the trigger input; when it is grounded momentarily the timing interval is started. Once started it cannot be retriggered. Pin 4 is the reset input; when it is grounded momentarily the timing interval is ended (the output goes low). With pins 2 and 4 connected together both functions are obtained with one push of the switch. When the reset function is not wanted pin 4 should be connected to pin 8, V_{CC}.

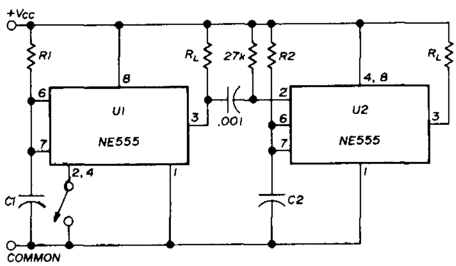

fig. 2. Two or more timer ICs may be cascaded when sequential timing is required.*

The NE555V IC can also be triggered by a negative-going pulse applied to pin 2. Thus, two or more timers can be cascaded for sequential timing as shown in **fig. 2.**

*For those circuits requiring two NE555V timer ICs, you might consider using the new dual-timer IC, the NE556, which contains two NE555s in one package. **Editor**

When pin 3 goes low at the end of a timing interval, a negative pulse is generated by the .001-μF capacitor and 27k resistor. This pulse triggers the start of the second timer IC. If a similar pulse circuit is connected to the second timer, and its output is connected to the trigger input of the first timer, the second timer automatically triggers the first timer as shown in **fig. 3**.

The second timer can be set to determine the *on* time of the first timer. When cause the first timer cannot be reset or triggered by the trigger pulse from the second timer while the first timer is in its timing interval.

For time delays of more than a few minutes a good quality tantalum capacitor such as a Sprague 150D should be used. For example, a ten-minute time delay requires a 100-μF capacitor and a 6-megohm resistor. Two possible applications for this circuit are station ID timers and repeater time-out timers.

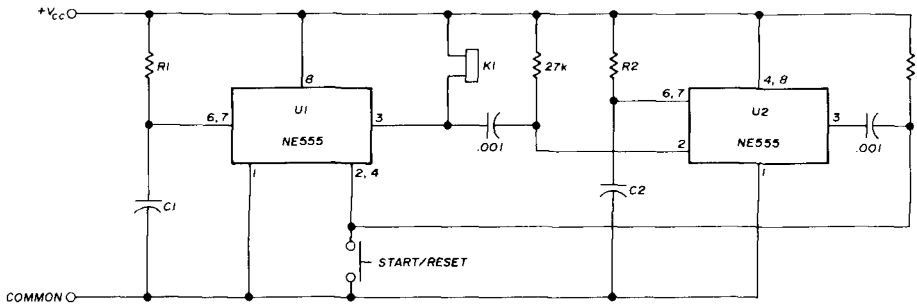

fig. 3. In this circuit the second timer, U2, automatically triggers the first, U1.

the timing interval of the second NE555V is completed a negative pulse is generated from the second .001 μF capacitor and 27k resistor. This pulse triggers the first timer which turns off the relay. Thus, the first timer determines the delay time interval and the second timer determines the *on* time of the relay.

At the end of the *on* time the first timer is automatically triggered and starts another timing interval. If the start/reset switch is closed momentarily, both timers are triggered. This does not matter be-

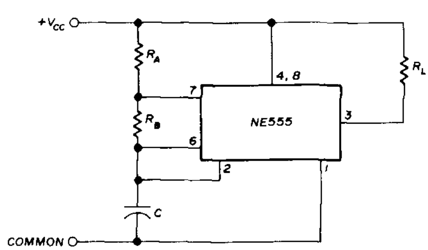

fig. 4. The NE555 may also be connected as an astable multivibrator but this circuit has several disadvantages when used as a timer (see text).

You might also consider using the astable multivibrator circuit (**fig. 4**). The charge and discharge times of the capacitor, C, are determined as follows: Discharge time (when the output, pin 3, is low) = $t2 = 0.685(R_b)C$. The charge time (when the output is high) = $t1 = 0.685 (R_a+R_b)C$. This circuit has two main disadvantages for longer time delays. For one thing, the first timing interval is longer than subsequent ones. This is due to the fact that the capacitor's charge starts from zero for the first time interval but thereafter operates between 1/3 and 2/3 of V_{CC}. The second disadvantage is that there is no manual reset capability. Even if the reset pin is connected to ground through a switch the capacitor will not be completely discharged, due to the time constant of R_b and C.

references

1. D. Blakeslee, W1KLK, "Time — IC Controlled," *QST*, June, 1972, page 36.
2. E. Mooring, W3CIX, "Simple Timer," *ham radio*, March, 1973, page 58.

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More Details? CHECK—OFF Page 94

enhancing cw reception through a simulated-stereo technique

A simple method for improving copyability of CW signals

Max Blumer, WA1MKP, Box 446, Woods Hole, Massachusetts 02543

A sharp audio filter is a great help in copying CW signals through noise and interference. A filter passband of 100 Hz will accommodate the keying bandwidth at 20 wpm and tolerate some short-term drift of transmitter and receiver.[1] However, such a narrow filter makes scanning of the band slow and difficult, and with high skirt selectivity the character of the received signal and its attack and decay may become distorted from ringing.

threshold gating

Higher noise reduction than possible from a tuned filter can be accomplished through threshold-gating, a technique in which the received and filtered CW signal is used to key a relay[2] or an electronic switch.[3] In turn, the relay or switch feeds the received and filtered signal or a sidetone oscillator to the headphones or speaker. Threshold-gating achieves its selectivity through the switching process. No signal is heard off frequency or between the dots and dashes. However, the original signal is highly distorted, especially in its attack and decay, or is completely replaced by a sidetone. As a result, feel for band conditions and for the quality and "signature" of the signal are lost, and any reply slightly off the filter frequency will not be heard at all.

This discussion suggests that you cannot, at the same time, use high filter selectivity and retain an essentially unaltered CW signal and full feel for the signal and the band. Therefore, sharp filters seem to have little value in contests and net operations, where you want to respond rapidly, often to signals which appear to one side of your receiver center frequency.

another approach

This is certainly true as long as you listen to the filtered signal only. However, if you were to listen simultaneously to one speaker fed with the processed signal and another speaker reproducing the "raw" CW signal, you could retain a feel for the band and would even hear chirp and clicks that extend beyond the filter passband. Also, if the received signal were drifting you would not lose it, and you could hear replies at some distance from the center frequency of your filter. Obviously, you would also lose some of the advantage of the filter and QRM and QRN would have returned to some degree.

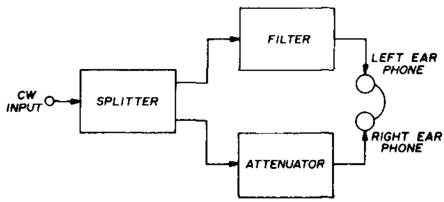

fig. 1. Block diagram showing how a simulated-stereo signal is derived from unfiltered receiver audio containing a desired signal plus QRM and QRN.

To this end, you can be helped by the ability of the brain to discriminate between signals which appear at both ears or only at one. To do this, the incoming CW signal is divided into two channels as shown in **fig. 1**. Half of the signal goes through a sharp filter to one ear, and the other half is passed unfiltered to the other ear. The level or balance control in the unfiltered side compensates for any attenuation of the filter. It is set so that a tone centered in the filter passband is heard by both ears at the same loudness level. This tone is then perceived stereophonically and appears centered within your head.* Any other tone is attenuated by the filter and will be heard predominately from the unfiltered channel. Consequently, all signals that are not passed by the filter appear to come from that *side which is receiving the unfiltered* channel.

*Because this effect may be enhanced or diminished by the phase relationship of the audio in the two earpieces, it would be desirable to try transposing the leads to one of the earpieces to see what happens. *editor*

results

The effect of this simulated stereo reception of CW signals is dramatic. Interfering signals and broadband noise appear to come from a point off to one side of the head. The desired signal, centered in *the filter passband, appears within or just* in front of the head and assumes a transparent clarity that is hard to describe. The signal-to-noise ratio is much improved. The character of the signal is preserved and ringing is either absent or less apparent than in monaural reception with the same filter. Chirp and clicks are readily noticed, and even drifting signals or DX *signals with multipath distortion* are readily copied.

The mind seems to concentrate automatically on the desired signal and to be relatively unaware of and undisturbed by the signals outside the filter passband. Yet, that information is present and an off-frequency reply is heard just as well as if no filter were in use.

practical considerations

I have used this approach with a simple passive toroid filter and with a more complex filter and threshold-gate combination. Both are effective. The latter has an advantage on some occa-

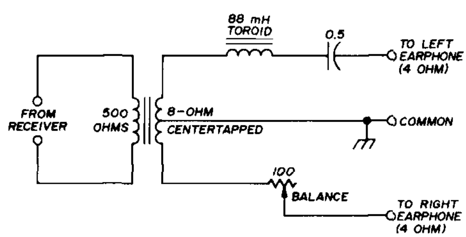

fig. 2. Circuit of complete simulated-stereo setup including simple but effective series-tuned toroidal filter.

sions, but for its simplicity and ease of adjustment the toroid filter is superior. The high-impedance audio signal from my HW101 is matched to the low impedance of the series-tuned toroid filter by a transformer, as shown in **fig. 2**. The center-tapped secondary provides two equal signals, one attenuated by the balance control and then fed to the right channel of a low-impedance stereo headset.

The toroid filter in the other half of the secondary resonates at 790 Hz and has a 3-dB bandwidth of 60 Hz; this frequency was chosen because the apparent stereo separation increases at lower frequencies. The output of the filter is fed directly to the left channel of the headset. The balance control should be adjusted on a moderately weak CW signal; a strong, steady tone, such as from a crystal calibrator, gives a slightly different balance.

First, peak the signal in the filter by listening only to the left earphone, then put on both phones and adjust the balance control until the signal appears centered. The range of the balance control is sufficient to move the signal from the far right across center to the left. Little further adjustment is required under differing band conditions.

The principle can be applied in various ways. Other input and output impedances can be accommodated with different transformers, or a parallel-tuned toroid filter (approximately 500 ohms) could be used. Other filters could be substituted, and instead of earphones a stereo amplifier and speaker combination used to give a good demonstration of simulated-stereo CW reception to interested listeners at a club meeting or hamfest.

references

1. E. Dusina, W4NVK, "The Simplest Audio Filter," *ham radio*, October, 1970, page 44.
2. R.M. Myers, W1FBY, "Recent Equipment: The Douglas Randall Scrubber," *QST*, November, 1971, page 51.
3. J.J. Duda, W2ELV, "Noise Reduction for CW Reception," *ham radio*, September, 1973, page 52.

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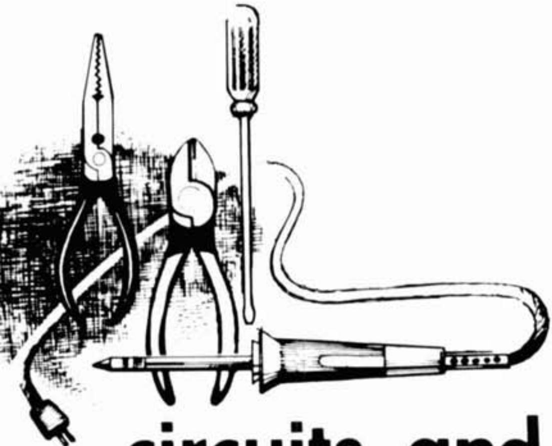

circuits and techniques

ed noll, W3FQJ

storage-battery QRP power

In a self-sufficient QRP station the storage battery is king. Although battery power need not be limited to low-power stations, QRP operation does permit you to gain knowledge of the science, gradually weaning you away from plug-in power, and over a period of time you can make your amateur station reasonably independent of the power mains. Solar power, wind power, etc., can make it so. The wind and solar conversion combination is attractive because on very cloudy days when there is no bright sunshine, there often is wind. Initially it might be expedient to take some power from the mains with an efficient battery charger, particularly when power demand is above the QRP level and there is a sequence of dark, windless days.

The radio amateur may be able to make a considerable contribution by demonstrating how energy can be derived from light, wind and other means. A house that is partly or completely self-sufficient in terms of heat and electrical power is a worthy objective.

Battery power at kilowatt and higher levels requires a well-ventilated hut or battery room, if lead-acid wet batteries are to be used. During the charge cycle batteries release some hydrogen gas which, if permitted to accumulate, becomes explosive. More gas is released when charging at a high rate or when you permit batteries to overcharge. Normally there is no hazard if the hydrogen gas circulates and intermixes freely with the atmosphere.

A ventilated window box will do for somewhat lower power levels. However, batteries must be selected to withstand the weather extremes of the site or mounting position. Nickel-cadmium batteries have fewer such problems and can be operated in more confined areas but are considerably more expensive at the higher power levels as compared to lead-acid types.

Some of you who lived in farm country before rural electrification may recall the small battery room just away from or attached to farm houses. Remember the wind chargers, small gasoline engines and dc generators? This is not so much nostalgia as some very practical dreaming as to how to obtain at least some degree of self-sufficiency, avoiding some of our

fig. 1. This gelled-electrolyte, 12-volt, 4.5 amp-hour battery is a relative newcomer to the rechargeable battery scene (photo courtesy Globe-Union).

fig. 2. Case and charger for gelled-electrolyte batteries (photo courtesy Globe-Union).

enslavement to mass energy sources plus the high cost that shortages trigger.

small lead-acid batteries

In the realm of QRP operation there are a variety of small lead-acid types. Visit your local motorcycle shop or take a look at the variety of types listed on the motorcycle batteries list in the Sears catalog. Two- and four-ampere-hour (Ah) types can be purchased at low cost. A typical price for a 4-Ah, 12-volt battery is not much more than 10 dollars. Such a low-powered battery displaces very little hydrogen and can be brought into your radio shack with little hazard. It can be charged by the smallest of chargers or by a small solar energy converter. On the basis of a 20-hour discharge period, the 4-Ah battery can supply 200 mA continuously for a period of 20 hours (4/20. Based on amateur operating practice it would be no problem to supply up to 10 watts for almost 8 hours of continuous operation without requiring a recharge.

Power capacity and current capability can be increased by connecting two or more of these small batteries in parallel. Much depends on your operating practices. In most cases operating time is substantially less than the projected maximums suggested by the previous figures.

gelled-electrolyte batteries

There is an attractive newcomer on the scene. It is a lead-acid battery that uses a gelled electrolyte, **fig. 1**. It is truly a portable lead-acid battery that can be mounted at any angle and, in some models, even charged at any angle. Others charge more efficiently with the battery upright but can be charged at other angles with some limited decline in the total number of recycles. The electrolyte is unspillable and lasts for the full life of the battery, avoiding maintenance and handling problems. The battery has a one-way vent that serves as a release when there is undue gas pressure, although in this style of battery there is much less gassing.

The gelled-electrolyte battery handles

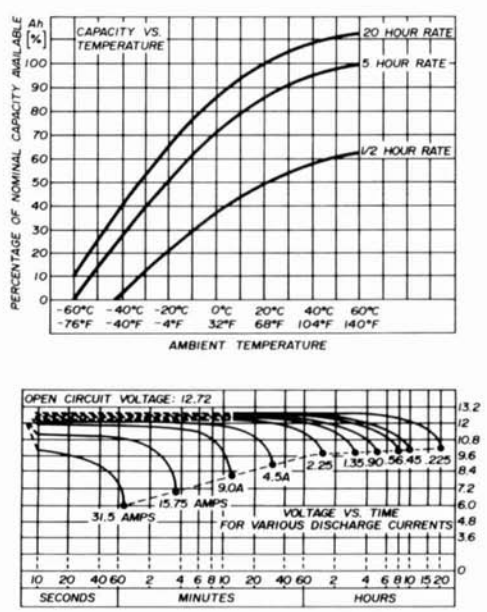

fig. 3. Operating characteristics of a 12-volt gelled-electrolyte battery, the Globe GC 1245-1.

temperature extremes very well and is capable of performing down to $-76°F$ ($-17°C$). It is tolerant of both overcharge and a deep discharge and provides long, maintenance-free shelf life. Batteries may be connected in series, parallel or series-parallel combinations to obtain desired voltage and current capability. Case and charger are provided for some types as shown in **fig. 2**.

The characteristics of the Globe-Union 4.5 ampere-hour, 12-volt battery are given in **fig. 3**. This battery would be a good choice for up to 5-watts QRP operation. Typical capacity figures are shown in item 2 of the specifications chart (**fig. 3**). Note, under item 9, the charge retention ability of the battery. When sitting unused for six months the charge drop-off is only 82%.

The first graph shows battery capacity as a function of the discharge rate. When discharged at the 20-hour rate the battery provides 100% capacity if operated at normal room temperature (about 69°F or 21°C). The percentage is lower for faster discharge rates.

Curves for various discharge rates are shown in the second graph. The top curve, representing the 20-hour rate, indicates a voltage decline to about 10 volts when the current demand is a continuous 0.225 amperes for a period of 20 hours. The final power delivered under this situation is about 2.25 watts (0.225 x 10). If a current demand of 1 ampere is made, note that the battery will provide almost four hours of continuous operation. This is about 10 watts of power for a continuous 4 hours. Thus, the 5-watt rating is a very conservative one.

In normal amateur operations you would have no trouble supplying 10 watts input to a QRP transmitter, and perhaps even more if you take care of the battery, preventing it from overcharging or dis-

GC 1245-1 Specifications

Nominal voltage	12 volts (6 cells in series)
Nominal capacity at:	
225 mA (20-hour rate) to 10.5 volts	4.5 Ah
430 mA (10-hour rate) to 10.26 volts	4.3 Ah
780 mA (5-hour rate) to 10.14 volts	3.9 Ah
2400 mA (1-hour rate) to 9.6 volts	2.4 Ah
Energy density (20-hour rate)	0.96 watt-hours/cubic inch
Specific energy (20-hour rate)	12 watt-hours/pound
Internal resistance of charged battery	approximately 60 milliohms
Maximum discharge current with standard terminals	80 amperes
Operating temperature range:	
Discharge	$-76°F$ to $+140°F$
Charge	$-4°F$ to $+122°F$
Charge retention (shelf life) at 68°F	
1 month	97%
3 months	91%
6 months	82%

fig. 4. This charger for gelled-electrolyte batteries provides either fast or float charging (photo courtesy Globe-Union).

charging to too deep a level. You can protect the battery's welfare by keeping an eye on its output voltage under load.

Power demand can be stretched even further if the battery is kept on a continuous floating charge with the permanent connection of a small charger, **fig. 4**. Current demand in amperes can be made for short periods of time.

The above operation also applies for daytime operation when using a solar energy converter as a float charger. Battery charge must be restored before the end of the day if capacity for night-time operation at lower power level is required.

The rated capacities (20-hour basis) for various Globe-Union gelled-electrolyte batteries are shown in **table 1**.

Prices are higher than for comparable wet electrolyte lead-acid types, but substantially lower than the cost of nickel-cadmium batteries. The combination shown in **fig. 2** is especially attractive for use with portable transceivers because it includes a battery-case and a charger. Batteries of this type do vent some hydrogen at the end of the charge cycle, or upon overcharge, and although they are less hazardous than wet electrolyte types, sensible ventilation and avoidance of sparks are advisable during the charging interval.

solar power as a charger

The solar energy converter has excellent battery charging capabilities. There are a number of ways in which you can use such a source. If the converter has adequate capacity it can even handle the initial charging of the battery. This is really not too much of a requirement if you are willing to charge the battery initially in a series of long-term steps.

The second technique is to use a conventional charger to obtain the initial charge. Then the solar energy converter can be pressed into service as either a float or trickle charge source. In this mode of operation the current demand is only one-quarter or even a smaller fraction of the initial charge current requirement. If the battery is critical of charge voltage or current it is possible to add a solid-state regulator to the output of the solar energy converter. Under less stringent requirements the protective diode that is a part of the solar device can prevent the discharge of the battery when the impinging light on the solar cells is inadequate to maintain the proper charge current.

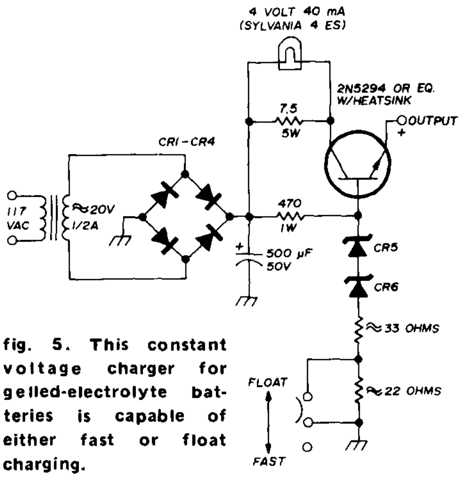

fig. 5. This constant voltage charger for gelled-electrolyte batteries is capable of either fast or float charging.

table 1. Rated capacity of various Globe-Union gelled-electrolyte batteries.

part number	nominal capacity
GC 210	0.9 Ah
GC 410	0.9 Ah
GC 610	0.9 Ah
GC 1215	1.5 Ah
GC 620	1.8 Ah
GC 426	2.6 Ah
GC 626	2.6 Ah
GC 1245	4.5 Ah
GC 660	6.0 Ah
GC 280	7.5 Ah
GC 680	7.5 Ah
GC 12200	20.0 Ah

battery chargers

There are several battery-charging arrangements relating to battery types and mode of operation. Insofar as the initial charge is concerned, some batteries can be charged quickly while others are preferably charged at lower current rates over a longer period of time. In general, nickel-cadmium types are charged at a slower rate than lead-acid types. Gelled-electrolyte types are usually charged at a slower rate than wet electrolyte cells.

For practically all types of rechargeable batteries the slow charge is much preferred over the fast charge, although certain battery types are less ill-affected by a fast charge, and in some circumstances you may have to sacrifice some battery life in favor of fast charging. Regular amateur radio operations are such that you can usually take advantage of slow charging, and, therefore, gain an extension in battery life.

table 2. Charging-current values for Globe-Union gel-cells.

battery rating	maximum initial charge current	approximate final current
0.9 Ah	0.15 Amp	10-20 mA
1.5 Ah	0.25 Amp	20-40 mA
1.8 Ah	0.30 Amp	20-40 mA
2.6 Ah	0.40 Amp	30-60 mA
4.5 Ah	0.70 Amp	50-100 mA
6.0 Ah	0.90 Amp	60-120 mA
7.5 Ah	1.20 Amp	80-160 mA
20.0 Ah	4.00 Amp	100-300 mA

Batteries can be charged and then discharged to a specified end voltage. At this time the battery is again charged fully, discharged, etc. In this mode of operation the battery is on charge whenever it is not being discharged by a connected load. Two other arrangements keep the battery on continuous charge. These are known as a constant-voltage charger (float voltage charge) or a constant-current charger (trickle charge). In the float voltage system preferred for gelled-electrolyte batteries the charge voltage is held constant while the current is free to vary. In contrast, the trickle charge plan preferred for nickel-cadmium batteries maintains a constant charging current while the voltage is allowed to vary.

The chart of **table 2** shows the initial charge current and fully charged current for the standard ratings of various Globe-Union gelled-electrolyte batteries. For example, the 4.5-Ah, 12-volt battery begins charging at a level of 700 mA. Full charge is indicated when the battery voltage reading is 14.4 volts and the charge current has dropped to a level between 50 and 100 mA. This corresponds to a final cell voltage of 2.4 volts.

When the same gelled electrolyte batteries are to be kept on continuous charge it is preferable that the charge voltage be held to 2.25 volts per cell, or for the 4.5-Ah version, a final voltage of 13.5 volts. Therefore, the charger must supply a constant 2.25 volts/cell (13.5 volts in the case of the 4.5-Ah, 12-volt battery).

To obtain the maximum number of recharge cycles the on-charge voltage initially should be such that the battery charge is brought up to 2.4 volts per cell. This charge should be continued until the current drops to the values shown in the tables. At this point the charger should be switched over to a float voltage of 2.25 volts per cell.

In practice as many as 200 to 400 full charge/discharge cycles are possible. If a float voltage charge is maintained, instead of permitting complete discharge, thousands of cycles of operation are feasible.

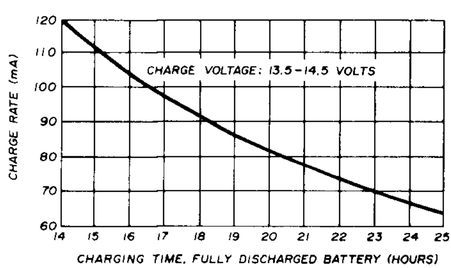

fig. 6. Battery charge data for the Eveready N86 nicad battery.

The charger shown in **fig. 4** permits both modes of charging. Note the switch that can be used to select either float or fast charge. An indicator lamp is turned on when the battery reaches 80% of full charge.

An example of a constant-voltage

charger that can be used for float or fast charge activity is shown in **fig. 5**. For fast-charge activity it provides exactly 14.4 volts. The constant voltage is maintained by the series power transistor and two series-connected voltage-regulator zener diodes. The precise value of the constant voltage is set by the two resistors connected between the anode of zener diode CR6 and common. In the float position only one resistor is used, the output voltage being maintained at 13.8 volts. An additional resistor is inserted in the circuit when the fast charge voltage of 14.4 volts is desired.

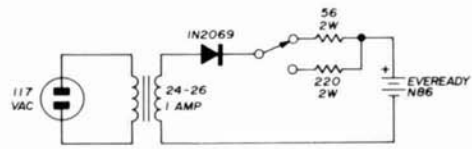

fig. 7. Basic constant-current battery charger for nicad batteries.

A nickel-cadmium battery is best charged with a constant-current source. A rather extended charge time is recommended and it is advisable that the charge rate not exceed the 10-hour figure. Information for the Eveready N86 12-volt battery (refer to information given in the August column) is shown in **fig. 6**. A series charge current of 120 mA will charge the battery fully in 14 hours. About 82 mA of charging current will do the same in 20 hours.

A basic charging circuit for nickel-cadmium batteries is shown in **fig. 7**. The circuit is fundamental although the values given are for the Eveready N86 battery. This circuit provides a charging current of 120 mA. After a battery has been fully charged, a trickle charge arrangement can be used to maintain full charge. Recommended trickle charge current for this battery falls between 24 and 40 milliamperes. This current value can be obtained by switching a higher value resistor into the constant-current charging current.

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the ham notebook

transmitter fail-safe timer

This timer was designed to provide for the disabling of an automatic RTTY transmitter in the event of control failure. In particular, this station has features which allow control codes to be punched on tape. After starting a tape the operator may leave the room to work on one of the many unfinished projects always waiting in the basement. Another feature allows a remote operator to punch tape on the LRXB composite tape set and then have it automatically replayed at its completion (operator on premises, but not necessarily at the control console). In either case a tangled tape or a mispunched control code could leave the transmitter keyed. There is also the possibility of the operator leaving the switching set-up in such a way that the system can not function properly. In all such installations it is necessary to provide some sort of backup control so that the channel is not blocked by a stalled automatic system.

This system allows the transmitter to remain keyed no longer than ten minutes (five minutes for the replay). If the time limit is exceeded, the transmitter is removed from the air and cannot be rekeyed until reset by the control operator. The timer is reset by the CW identification device. Hence, it is possible to make transmissions longer than ten minutes, but only if the proper identification is given. Station control wiring prevents a remote station from inserting the CW ID sequence on a replay tape. However, such codes may be inserted when the control operator punches tape.

Originally I planned to use a NE555 timer IC to set the ten-minute time period. However, I found it impossible to reach the ten-minute limit with the capacitors I had on hand. Since such capacitors were also expensive and somewhat difficult to find, it was decided to go to a shorter period and use a 7490 divider to extend the period. This approach costs no more than the original plan with a high quality/cost capacitor, and it allows for other timing periods as well.

The NE555 oscillator is set at approximately one cycle every 1.4 minutes. The output is introduced to the 7490 decade divider. Pin 11 of the 7490 goes high on the eighth count (approximately 11.2 minutes) after the 7490 is enabled by U4B. Then the output of U3D goes low, forcing the output of U3C high. When pin 8 of U3C goes high, Q1 conducts, removing the base bias from Q2. When Q2 stops conducting, the disable relay opens, resetting a holding relay in the control unit and disabling the entire automatic system. The Q1, Q2 configuration was chosen so that the disable relay would be normally on and power supply failure would also reset the system.

When the replay is enabled U3A, pin 3, goes high. Pin 8 of U2 goes high on a count of four (approximately 5.6 minutes); U3B goes low, shutting down the disable relay as previously described.

The 7490 is enabled when the transmitter is on (U4D pins 12 and 13 low). If, however, pin 3 of U4A is forced low (by the CW ID device), then U4B pin 6 goes high, resetting the 7490 to its zero count. It has not been found necessary to reset the oscillator, but this may be done for increased accuracy in the timing periods.

If either the transmitter or the CW ID is keyed, Q3 conducts, keying the *transmit* relay. Also, when the CW ID is keyed, Q4 conducts, keying the CW ID relay which is used to disable the station tape readers and keyboard during the identification sequence.

When the replay is keyed, Q5 pulls the transmitter line low (a single transistor was used here to eliminate the need for another IC package), enabling the 7490 and keying the transmitter. As mentioned above, keying the replay allows the four count from the 7490 to reach Q1 via U3, setting the time-out period for the replay at half the value chosen for operator initiated transmissions.

A revision planned for the future would include an *idle line* detector to sense the lack of regular transitions from mark to space on the loop to time the disable relay out in sixty seconds. This would decrease the recovery time for the channel in the event that a tape reader is not properly enabled or some other malfunction keys the transmitter, but does not allow any data to be sent.

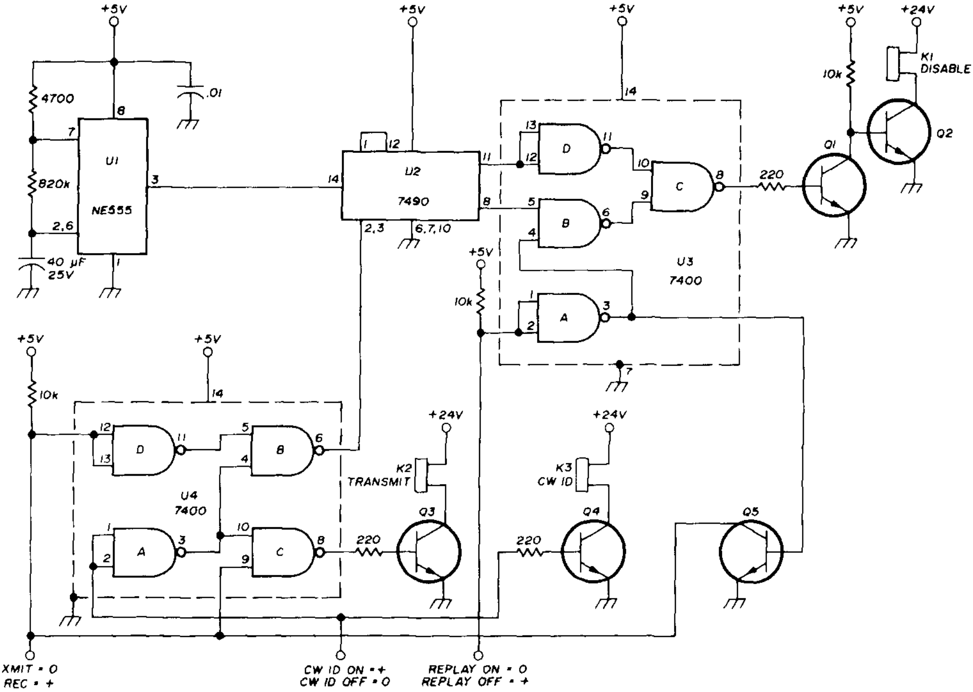

fig. 1. Circuit for the fail-safe timer. Nearly any npn transistors may be used at Q1 - Q5. Relays are Potter and Brumfield KH4703, 24-volt coils.

The circuit described here has been in operation for a period of four months. It has never timed out a transmission of proper duration and on several occasions it has removed the transmitter from the air when transmissions were too lengthy (and a few times when the proper control codes were not received by the system).

The logic draws less than 100 mA at five volts. The relays are 24-volt P&B KH4703 and are operated from the unregulated dc supply. This supply is 18 volts under the load of the five-volt regulator, and is quite adequate for reliable operation of the relays. The unit is constructed on perf board and is enclosed with the CW ID device in an rf-proof enclosure. All leads entering or leaving the enclosure are bypassed.

Notice that since the timer is reset by the CW ID, the timer would not function properly if the CW ID were inserted automatically every eight to ten minutes. The CW ID must be inserted (possibly on tape) by the control operator for the transmitter to run longer than the limit set by the timer.

Robert Clark, K9HVW

waveguide klystron cooler

In many amateur microwave assemblies, it is impractical or even impossible to obtain adequate air flow around reflex klystrons or other signal sources. One solution is a simple water-cooled section of waveguide. Such a solution is more practical than fabricating a water jacket for the klystron itself because the guide section can be used with any flange-mounted klystron or Gunn diode. An example unit is illustrated in **fig. 2**. It was fabricated from a short section of WR-90 guide with UG-39/U flanges and 1/4-inch (6-mm) water lines. The klystron, a Varian 6975, was operating with a beam power of 9.0 W. The temperature reduction at the worst case was greater than 15°C (see **fig. 3**). The coolant flow rate was 0.6 liters/minute, coolant temperature was 25°C.

John M. Franke, WA4WDL

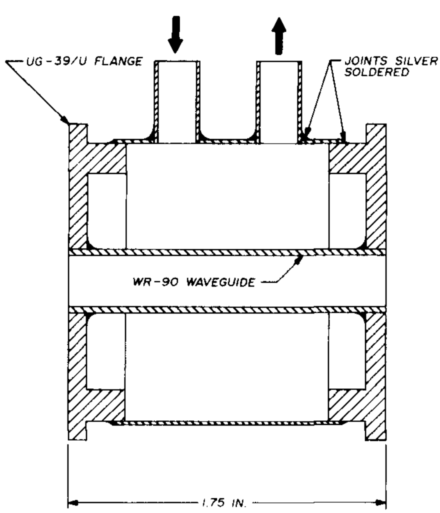

fig. 2. Water-cooling jacket for WR-90 waveguide. Input and output tubes are ¼" (6 mm) diameter.

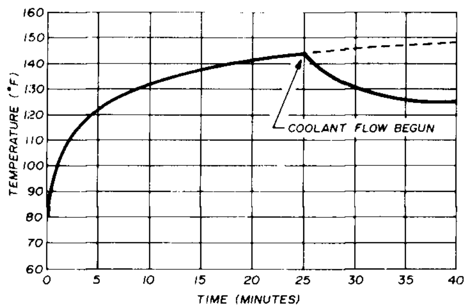

fig. 3. With coolant flow rate of 0.6 liters/minute (25°C coolant temperature) klystron temperature decreased 15°C, minimum.

protector guards against auxiliary battery drain

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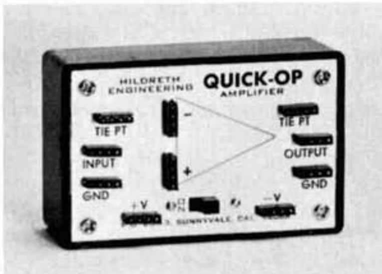
quick-op amplifier



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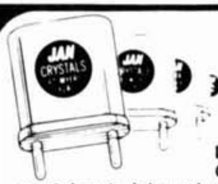

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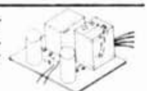

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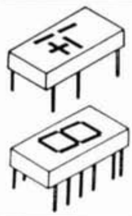

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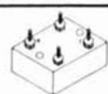

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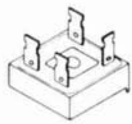

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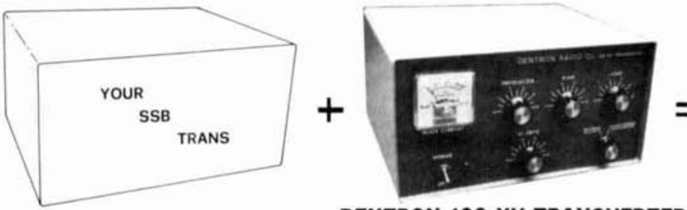

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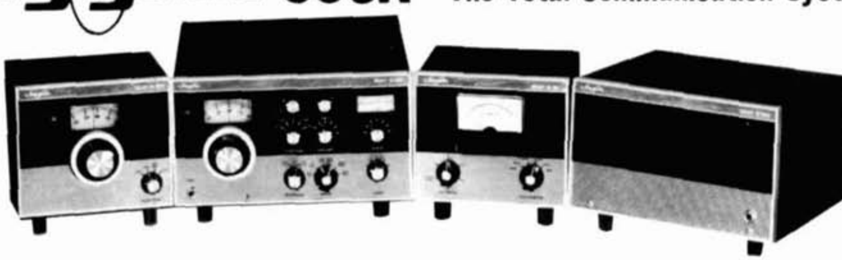

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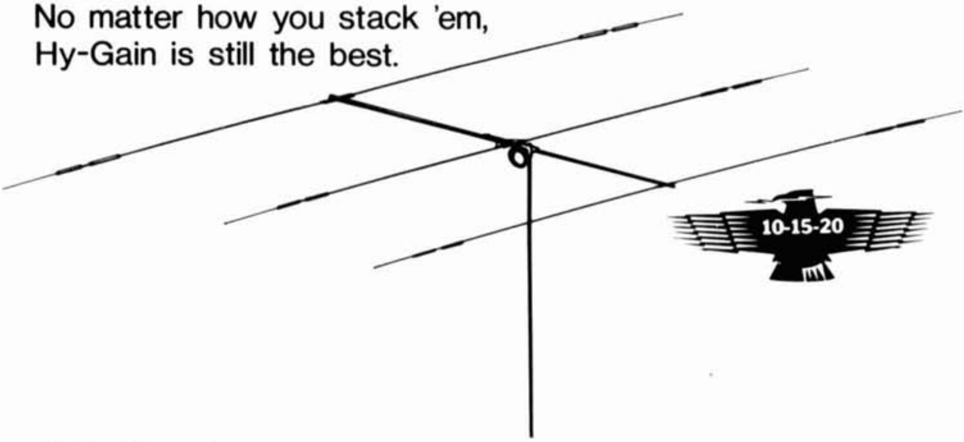

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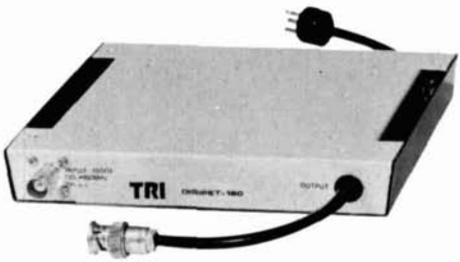
(PLUS 130 MHz TO 160 MHz)



Perfectly designed for the radio amateur who wants quality, accuracy *and* economy.

If you operate around the 50 MHz band, we can offer you the Digipet 60—it measures a range of 1 kHz to 60 MHz—and it costs less than $300.

However, if you operate up around 140 MHz, you'll want the Digipet 160 converter. It costs an additional $50 and, mated-up with the Digipet 60, measures the critical range from 130 MHz to 160 MHz.

Its AC or DC operable with complete overload protection, plus being stable (aging rate: 1 part in 10^6/week), small (7" deep x 2½" high), sensitive (50 mVm's), flexible (five numerical-tube digits) and accurate (resolves to 1 kHz or 1 Hz, depending on gate time selected).

Write *immediately* for more information.

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VALU-PAK

ALL MERCHANDISE IS NEW UNUSED SURPLUS AND IS SOLD ON A MONEY BACK GUARANTEE.

LED 7 SEGMENT READOUTS

		EACH	10 PAK
MAN-3	.115" w/RH decimal (claw)	$ .90	$ 8.00
MAN-3	.115" w/RH decimal (flat leads)	.80	7.00
MAN-4	.19" w/RH decimal (DIP)	2.00	17.50
DL 33	.1" 3 digits in one 12 pin DIP	2.50	22.00

LED DISCRETE DEVICES

		EACH	10 PAK
MV50	axial micro-mini red	$ .15	$ 1.00
MV5021	diffused dome red	.25	2.00
MV4	2 WATT hi-pwr red (STUD)	2.25	20.00
MV4H	2 WATT hi-pwr red (hi-dome)	2.50	22.00
ME5	2 WATT hi-pwr INFRA-RED	2.50	22.00

LINEARS

		EACH	10 PAK
LM301	MINI-DIP Hi perf. AMPL	$ .50	$ 4.25
LM307	MINI-DIP Op AMP (super 741)	.50	4.25
LM309H	TO5 5V Regulator	.90	7.50
LM309K	TO3 5V 1A Regulator	1.75	15.00
LM311	8DIP Hi perf. Volt. Comparator	1.00	8.00
LM320	TO3 5V Negative Regulator	1.90	17.00
LM320	TO3 12V Negative Regulator	1.90	17.00
LM320	TO3 15V Negative Regulator	1.85	17.00
LM380	14DIP 2 WATT Audio AMPL	1.70	16.00
LM381	DIP Low noise Stereo Amp.	1.75	15.00
9601	DIP Monostable Multivibrator	.55	3.95
9602	DIP Dual 9601	.65	5.00
555	8MINI-DIP TIMER	1.20	9.50
723	DIP Precision Voltage Regulator	.90	7.50
741	8MINI-DIP Hi perf. Op Amplifier	.45	3.95

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		EACH	10 PAK
CD 4016	Analog Switch	$1.20	$10.00
74C74	Dual D FF	1.20	10.00
74C76	Dual JK FF	1.30	11.00
74C195	4 bit Shift Register	2.30	20.00

CT5001 CALCULATOR CHIP SPECIAL!

Forty-pin calculator chip will add, subtract, multiply and divide: 12-digit display and calculate; chain calculations; true credit balance sign output; automatic overflow indication; fixed decimal point at 0, 2, 3, or 4; leading zero suppression.

$5.95 EACH   10 FOR $49.00

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TTL	EACH	10 PAK
7400 HN	$ .22	$ 1.80
7401	.28	2.50
7402	.28	2.50
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7404 HN	.22	1.80
7405	.28	2.50
7406	.40	3.50
7408	.30	2.60
7410	.28	2.50
7411	.40	3.50
7416	.45	3.80
7420	.28	2.50
7426	.35	3.00
7430	.22	2.00
7441	1.25	10.00
7445	1.10	9.00
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7460	.22	1.80
7473	.50	4.50
7474	.50	4.50
7483	1.00	9.00

All IC's are DUAL IN LINE (DIP) unless otherwise stated. Please ask for data sheets as required. All parts are marked and are tested for function. Some parts are house numbered, (HN).

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flea market

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ROCHESTER, N. Y. — Hamfest date of 1975 — May 31st. Marriott Inn is new headquarters. Information? Write WNY Hamfest, Box 1388, Rochester, N. Y. 14603.

QSLs. SECOND TO NONE. Same day service. Samples airmailed 25¢. Ray, K7HLR, Box 331, Clearfield, Utah 84015.

WANT OLD RADIO SHOW TRANSCRIPTION discs. Any size or speed. Send details to, Larry Kiner, W7FIZ, 7554 132nd Ave N.E., Kirkland, Wa. 98033.

RESISTORS: Carbon composition brand new. All standard values stocked. ½W 10% 40/$1.00; ¼W 10% 30/$1.00 — 10 resistors per value, please. Minimum order $5.00. 15W RMS 1C Audio Amplifier — Panasonic. Frequency response 20Hz-100 kHz. ½% distortion. Price $6.95 Postpaid. Pace Electronic Products, Box 161-H, Ontario Center, New York 14520.

HAM RADIO APRIL 1970 MISSING: K6MHQ needs it to complete files. c/o AM. Radio Service, FPO 96620.

WANTED: ARC-51, 618T-1, ARC-102, FM-633, ARC-131, 807A Wilcox, Transceivers. Pay Cash. Bob Sanett, 616 S. Holmby Ave., Los Angeles, CA. (213) 279-1275.

PERSONAL ATTENTION plus the best cash deal anywhere is what you receive at Queen City Electronics in the heart of the Midwest. Queen City carries all major brands including Drake, Tempo, Kenwood, Yaesu, Swan, Regency, Clegg, Standard, Icom, Genave . . . Write or phone us for your equipment needs. Queen City Electronics, Inc., 7404 Hamilton Avenue, Cincinnati, Ohio 45231, (513) 931-1577.

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TELETYPEWRITERS — Kleinschmidt — portable, fixed, sets, punches, parts, reconditioned, reasonable. Mark/Space Systems, 3563 Conquista, Long Beach, Calif. 90808. 213-429-5821.

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RTTY EQUIPMENT FOR SALE including machines, parts, gears. Send us a list of your teletype needs. Atlantic Surplus Sales, 1902 Mermaid Ave., Brooklyn, N. Y. 11224.

FREE: 12 Extra crystals of your choice with the purchase of a new Regency HR-2B at $229. Send cashier's check or money order for same-day shipment. For equally good deals on Collins, Drake, Kenwood, Standard, Clegg, Swan, Icom, Yaesu, Genave, Hallicrafters, Tempo, Ten-Tec, Venus, Hy-Gain, CushCraft, Mosley, and Hustler, write to *Hoosier Electronics, your ham headquarters in the* heart of the Midwest. Become one of our many happy and satisfied customers. Write or call today for our low quote and try our individual, personal service. Hoosier Electronics, R.R. 25, Box 403, Terre Haute, Indiana 47802. (812)-894-2397.

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

DEAR FANS: Distortion meter, rf sweep generator, af sweep generator, function generator, miniature 80M receiver, etc. Many built for articles in Ham Radio, etc. Sase for details and prices. Ray Megirian, K4DHC, Box 580, Deerfield Beach, Fl. 33441.

MEMPHIS AREA HAMFEST, Sunday, October 6 at State Technical Institute, conveniently located at Interstate 40 and Macon Road (Exit 11). Demonstrations, displays, FM forum, MARS meetings, flea market, XYL entertainment, prizes. Informal dinners Saturday night. Dealers and distributors welcome. Talk-in on 3980, .34-.94 and MARS. Contact Harry Simpson, Box 27015, Memphis, TN 38127, phone 901 358-5707.

NEW PARTS BARGAINS: Calrad KW SWR-relative power dualmeter bridge 24.95; Hygain TH6DXX — see this month's ad. CDE Ham-2 109.00; Belden 8448 8-wire rotor cable 12¢/ft; #22GA/7STD phosbronze longwire-rhombic antenna wire, plastic coat, high tensile 2.50/1000-ft; new Brandes headphones (J) 5.50; many new Sprague capacitors, write needs; doorknobs: Sprague 500PF/20KV 2.50; CDE .001/10KV 1.95; Erie Padder Caps 3-12PF & 8-50PF, both 49¢ coax: RG62B/U 8¢/ft; RG71/U 8¢/ft; RG13B/U 15¢/ft; Belden, Consolidated RG8 foam 8214 18¢/ft; Amphenol PL259 59¢; Motorola semi-conductor data series books 7.50; Rider, Tab, Radio Publications, ARRL, Ameco, Callbooks; many old tubes — write needs; new panel meters — write; H-P LEDS series 5082 - 99¢ ea; new Raytheon, GE 811A 7.95; 15.00/pr; Sorensen ACR2000VA AC regulator 150.00; GE receiving tubes 50% off list; KY65 code keyer (plastic wheels) 5.95; free flyers. All items new, guaranteed. Prices fob Houston. Madison Electronics, 1508 McKinney, Houston, Texas 77002. 713/224-2668, Nite 713/497-5683.

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

TRADE: Collins 390A & manual. Very good condition, for late model transceiver. Write George Keys, WA6KAA, 1334 N. Broadway, Santa Maria, Ca. 93454. 1-805-925-7755.

DO-IT-URSELF DXPEDITION — Stay at ZF1SB — Caymen Is. Vertical antenna and Caribbean at your doorstep. Diving/fishing if band folds. Write Spanish Bay Reef Resort, Box 800K, Grand Cayman, B. W. I.

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QSL'S — BROWNIE W3CJI — 3035B Lehigh, Allentown, Pa. 18103. Samples with cut catalog 35¢.

TECH MANUALS for Govt. surplus gear, $6.50 each: URM-25D, URM-32, R-220/URR, R-274/FRR, R-390/URR, TS-497B/URR, TS-382D/U, LM-21, PRC-10. Thousands more available. Send 50¢ (coin) for large list. W3IHD, 7218 Roanne Drive, Washington, D. C. 20021.

ONLY HR REPORT brings you the news of amateur radio via air mail as it happens, not weeks or months later. Send for a one year subscription, 24 issues plus extras. Only $12.00. HR REPORT, Greenville, NH 03048.

4-1000A, socket w/dome, blower, fil xfmr, air flow switch, trade for Ham-M or price of same — WA2DCA - P. O. Box 104, Cherry Hill, N. J. 08034.

WANTED. BLONDER-TONGUE Field Strength Meter Model 4127. No substitute. Also Simpson 260, 261 or 270. State price and condition. Marvin Loftness, 115 W. 20th, Olympia, WA 98501. Phone 206-357-8336.

FOR SALE: MOTOROLA MODEL #C74BBY 90 watt compa station with blower, 450 MHz repeater with 6 dB gain antenna @ $350.00 as is, (working while pulled from service). Also available: 125 ft. 7/8 Heliax @ .60/ft. and UHF fittings @ $7.50 each. F.O.B. Topeka, Kansas.

PACKRAT HAMARAMA is Sunday, October 6th at the Bucks County Drive-In Theater on Rt. 611 in Warrington, Pa. This is near exit 27 of the Pa. Turnpike and north of Willow Grove, Pa. Huge flea market, auction. Festivities begin at 9:30 a.m. and auction starts at 2 p.m. — RAIN or SHINE. Registration is $1.00 and tail gate selling $2.00. Talk-in 146.52, 52.525 and the club repeater WR3ACD - 222.98 and 224.58 out. For further information and flyer with map, SASE to K3MXM, Lee A. Cohen, 8242 Brookside Rd., Elkins Park, Pa. 19117.

WANTED — TPL; Want 100 watt, 150-174 MHz, TPL multiplier — PA cage and Hi-Band receiver RF card. State price, condition, and GE PN. Will swap with 6 meter equipment. G. Lose, 907 Minnesota #6, Troy, MI 48084.

VERY in-ter-est-ing! Next 5 big issues $1. "The Ham Trader," Sycamore IL 60178

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VOLUNTEER needed in Orange, California area to handle traffic for Bible translators. Also need RTTY gear, ham gear; tax deductable. Write Mike Naruta, WA8BHR, 4466 Burtch, North Street, MI. 48049.

QUALITY CABLE TIES (6" nylon), half price, $2.75/100 postpaid. Joe Ottinger, 106 Sheridan Ct., Leavenworth, KS 66048.

CANADIANS — We carry a broad line of electronic parts, including most solid-state devices, LEDs, ICs. Send for free flyer to: Ken, VE1AOJ, Dartek Electronics, Dept. H, Box 2460, Dartmouth, Nova Scotia B2W 4A5.

PRINTED CIRCUIT TECHNIQUES for the hobbyist. Booklet: $2.00. H. S. steel and carbide drill bits and PC artwork. Send SASE for flyer. Trumbull, 833 Balra Dr., El Cerrito, Ca. 94530.

FOR SALE: MOTOROLA TLN 6185A Quik Call Decoder with reeds. $20 each. Various Motorola and G. E. mikes, control leads, cables, manuals, and tubes. WA7PUD, 503-252-0303.

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WORLD QSL — See ad on page 93.

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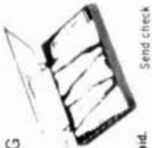

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More Details? CHECK—OFF Page 94

SURPLUS TEST EQUIPMENT, VHF and microwave gear; write for bulletins. David Edsall, 2843 St. Paul, Baltimore, Md. 21218.

QSL's, Sample catalog 20¢. N & S Print, P. O. Box 11184, Phoenix, Ariz. 85061.

MANUALS *for most ham gear made 45/65,* some earlier. Send SASE for specific quote. Hobby Industry, WØJJK, Box H-864, Council Bluffs, Iowa 51501.

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