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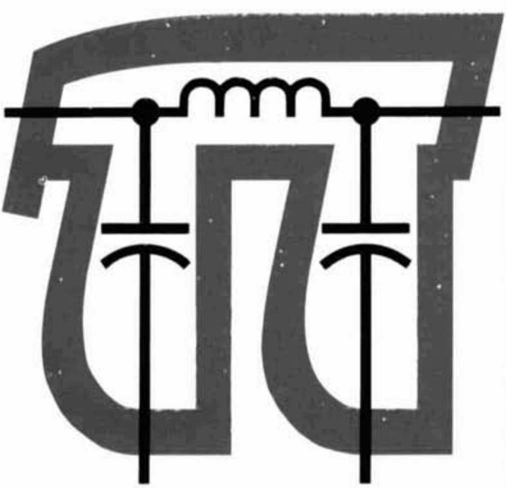
SEPTEMBER 1972

high-frequency power amplifier PI NETWORK DESIGN



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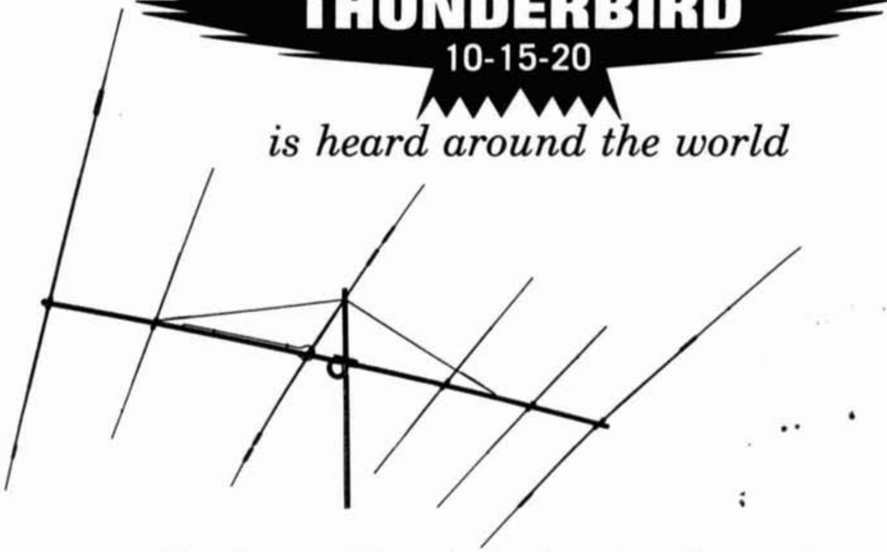

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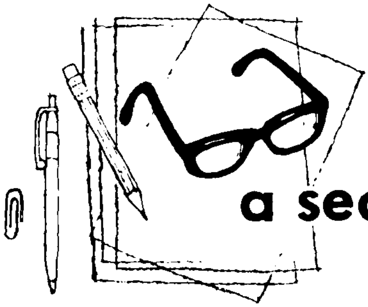

a second look

by jim fisk

A whole new family of ICs which is blooming in the development stage promises to revolutionize communications. These new ICs, called OICs (pronounced *oyks*) for optical integrated circuits, use technology borrowed directly from the semiconductor IC industry.

OICs are closely related to laser communications, and provide lasing, coupling, modulating, filtering and multiplexing for future optical communications systems. Practical application of these new devices is anywhere from two to ten years in the future, depending on who you talk to. However, it is just a matter of time before optical communications systems carry the bulk of industrial traffic, including telephone, digital data and television. The big advantage of the optical system, of course, is the huge message-carrying bandwidth which is available.

Early optical communications systems depend upon short laser links, but in future systems there will give way to fiber-optic *wires* which carry the signal from point to point. The optical fiber, already developed by Corning Glass, will carry a coherent laser signal with relatively small losses. OICs will be used to process the optical signal once it reaches its destination.

Both active and passive types of OICs are being developed at the present time. The most successful passive types use a thin glass film deposited on a glass plate. A masking and etching process similar to that used by IC manufacturers removes the excess glass deposit. These passive structures can be formed into frequency-selective filters and directional couplers as well as straight signal-carrying optical waveguides.

Development work on active OICs is progressing on several different, divergent fronts. Some scientists are fabricating optical waveguides in gallium-arsenide compounds, a familiar semiconductor material. Waveguide effects have also been produced in zinc selenide diffused in cadmium. The materials and processes being developed for OICs remind me of the then-new and strange semiconductor processes which spawned the transistor industry in the late 1950s.

Many problems will have to be solved before optical communications and OICs become a practical reality, including a method of putting laser energy into the device and taking it out. Two methods that show promise include prisms placed very close to the surface and optical gratings etched on the waveguide surface. Prisms are much more efficient than the gratings, but they cost considerably more and are more difficult to build. However, research is progressing in this area, and in all probability, a low-loss grating will eventually be developed.

Although few amateurs have added laser-communications to their repertoire, some amateurs have had good success, including the two-way laser phone contact of WA8EWJ and W4UDS, and W4KAE's nearly 4-mile QSO with a keyed laser beam. With the availability of new optical equipment, including OICs, range will increase, and someday, in the not too distant future, we may even have an amateur band in the visible light range. Anyone for a schedule on 500 Terahertz?

Jim Fisk, W1DTY
editor

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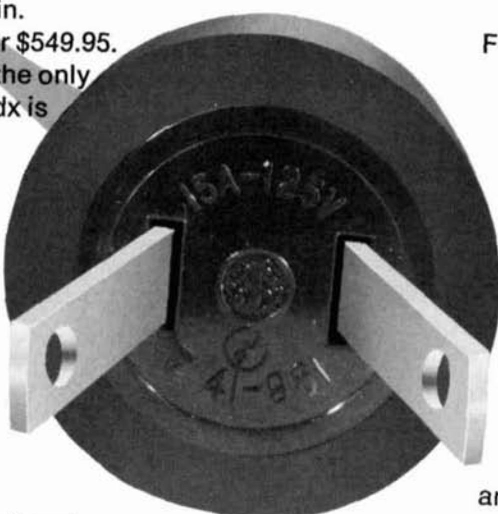

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high-frequency power amplifier pi network design

A complete discussion of pi and pi-L network design, with computer-derived component values for a wide range of operating conditions

Irvin M. Hoff, W6FFC, 12130 Foothill Lane, Los Altos Hills, California 94022

The design of rf power amplifiers has always fascinated the typical radio amateur, and it remains one of the few fields in which a person of modest technical capability can still actively participate. Although the number of home-built transmitters has steadily diminished as more commercial companies have entered the market, many amateurs still like to design and build their own final amplifier. The information contained in this article should greatly assist those so inclined. Many interesting comparisons will be presented between amplifiers running at different power levels as well as pertinent computer-derived data for the proper selection of component values.

With single sideband and its legal 2-kW PEP maximum input power, certain problems crop up which many amateurs overlook or are unable to handle. This is because the operator wants to run the amplifier at one power level for ssb and another for CW. The problems are compounded when the operator also wants to run RTTY, which is 100% key-down continuous-carrier operation.

There is also a growing tendency to build power amplifiers with higher plate voltages than were common a few years ago. Part of this trend is due to the fact that the newer power tubes provide maximum performance at high plate voltages. Many of the pi-network design charts previously published have not been extended to include these higher operating voltages.

The pi network is so named because of its resemblance to the Greek letter pi as shown in **fig. 1.** The same network in its electrical form with input and output impedances is shown in **fig. 2.** Since most *amateurs use 50-ohm coaxial transmission* line, the output load impedance of the pi network is usually 50 ohms.

When the pi network is used in a power amplifier, the circuit looks like that shown in **fig. 3.** The antenna provides the output load impedance, Z_L, and the power tube provides the input load impedance Z_p. Since the plate load impedance usually falls into the range of 1200 to 5000 ohms, the pi network transforms the high impedance of the vacuum tube into the 50-ohm antenna load. It performs this job quite efficiently, and with predictable results.

harmonic attenuation

Actually, the pi network is a basic form of three-pole low-pass filter. With proper care in design it will attenuate the second harmonic by 35 dB or more.[1] This would be for a loaded Q of 12; if the Q is doubled, attenuation is increased by approximately 6 dB.

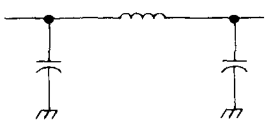

fig. 1. The pi network is so named because of its basic resemblance to the Greek letter π.

The pi-L network shown in **fig. 4** consists of a standard pi network with an additional inductor. Since the pi-L network is a four-pole low-pass filter, second harmonic attenuation is increased to approximately 50 dB. This is particularly important if you want maximum suppression of TVI.

In addition to increased harmonic suppression, the pi-L network offers greater bandwidth for a given variation in operating Q, requires less output capacitance, and is able to operate efficiently with lower Q at very high plate load impedances. These advantages will become more apparent later in this article.

plate load impedance

The dc plate resistance of a vacuum tube, at a given input power level, can be calculated with Ohm's law: R = E/I, where E is the dc plate voltage and I is the dc plate current. However, since we are dealing with an ac circuit, this is of little value. What we need to know is the plate load *impedance.* This is given approximately by the following equation which has been derived from the complex functions of a vacuum tube operating in class B.

$$Z_p \approx \frac{E}{1.57\, I} \quad (1)$$

where Z_p is the plate load impedance, I is the indicated plate current and E is the dc plate voltage.

When the vacuum tube is operated in class C, as for CW, the plate load impedance is approximated by

$$Z_p \approx \frac{E}{2 \cdot I} \quad (2)$$

If you are using a linear amplifier that runs with very high idling current, and approaches class A, the following approximation for plate load impedance would be more appropriate.

$$Z_p \approx \frac{E}{1.3\, I} \quad (3)$$

Zero-bias grounded-grid linears are usually thought of as being class B, but there is no hard and fast rule in this regard. A number of articles have been written on this subject, and you are likely to have already formed some opinions of your own.

Consider the case of a class-B rf power amplifier with a 2100-volt plate power supply and indicated plate current of 476 mA (1 kW input). As calculated from **eq. 2,** the plate load impedance is 2800 ohms:

$$Z_p = \frac{2100}{1.57 \cdot 0.476} = 2800 \text{ ohms}$$

Typical plate load impedances for various power levels and different operating voltages and currents are shown in **table 1**. It can be seen from this data that the plate load impedance rises to very high levels when the plate voltage is increased above 4000 volts. More amateurs than might be expected use 4000 to 6000 volt power supplies, and many of the associated problems have not been adequately discussed in the past.

circuit Q

The letter Q stands for quality factor, and is used to describe, in simple numerical terms, the efficiency and performance of capacitors and inductors. Actually, there are two types of Q – *loaded* Q and *unloaded* Q. The unloaded Q is the inherent quality factor of the component itself; loaded Q is the quality factor of the component when it is used (and loaded down) by the circuit.

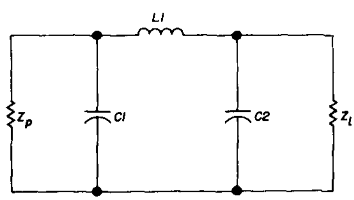

fig. 2. Basic pi network showing the input and output load impedances. The input load impedance in transmitters is the plate load impedance; output load impedance is usually 50 ohms in amateur stations.

The unloaded Q of a component is given by

$$Q_u = Q\ (\text{unloaded}) = \frac{X}{r} \qquad (4)$$

where X is reactance and r is ac resistance. The unloaded Q of a high-quality capacitor might be 1000 or more, and a silver-plated inductor might have an unloaded Q of more than 500.

The loaded Q of a pi network is usually on the order of 10 to 20 for maximum harmonic attenuation, and is given by:

$$Q_o = Q\ (\text{loaded}) = \sqrt{\frac{Z_p \cdot Z_L}{Z_L}}$$

where Z_p is the input impedance to the network, and Z_L is the output impedance.

When designing pi networks a value of

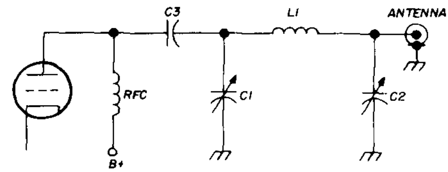

fig. 3. Pi network used in the output of a rf power amplifier is coupled to the power tube through a dc blocking capacitor (C3). C1 is the tuning capacitor, C2 is the loading capacitor, and L1 is the tank inductor.

loaded Q is chosen on the basis of harmonic attenuation, and is used in the design equations to determine the inductance and capacitance values for a given operating frequency.

L networks

A typical step-down L network is shown in **fig. 5**. This network is used to transform its input impedance to a lower output impedance. The Q of this circuit is entirely dependent upon the ratio of the input and output impedances as given in **eq. 5**.

For example, if the input impedance to an L network is 2500 ohms, and the output impedance is 50 ohms, the loaded Q of the network is 7:

$$Q_o = Q\ (\text{loaded}) = \sqrt{\frac{2500 - 50}{50}} = \sqrt{49} = 7$$

However, a loaded Q of 7 is much too low for good harmonic suppression. To determine the L-network input im-

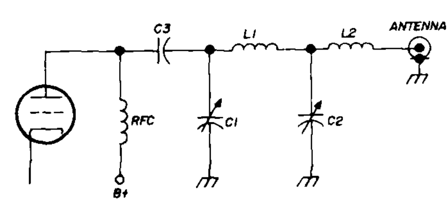

fig. 4. The pi-L network requires an additional inductor, and provides increased second harmonic attenuation.

pedance required to provide a desired value of loaded Q, **eq. 5** is rearranged as shown below:

$$Z_p \approx Z_L (Q_o^2 + 1) \qquad \textbf{(6)}$$

For example, with an output load impedance of 50 ohms, and a desired loaded Q of 12 (for good harmonic suppression), the required input impedance is 7250 ohms. This is very restrictive and does not allow the designer sufficient latitude. So, although the L network is extremely efficient (98% typical), a pi network is usually used in transmitter output circuits.

pi network design

You can think of the pi network as being two L networks in tandem as shown in **fig. 6**. The first L network is a step-down type while the second L network is reversed for impedance step up. As an example, consider the case where the input impedance to the dissected pi network in **fig. 6** is 2900 ohms. With a Q of 12, the first L network would step the input impedance down to 20 ohms. This is often called the *virtual* impedance.

$$Z_L = \frac{Z_p}{Q_o^2 + 1} = \frac{2900}{12^2 + 1} = \frac{2900}{145} = 20 \text{ ohms} \qquad \textbf{(7)}$$

The second L network would then be designed to raise this virtual impedance of 20 ohms to 50 ohms to match the antenna. The Q of the second section would be quite low, on the order of 1.5.

As the input impedance is increased with Q held constant, the virtual impedance increases, and when the virtual impedance is equal to the desired output impedance, the pi network reverts to an L network. For example, with a plate load impedance of 7250 ohms and a Q of 12, the virtual impedance is 50 ohms. This is the maximum possible *impedance transformation* for a Q of 12 and an output impedance of 50 ohms.

Normally, about 70% of the maximum possible impedance transformation is used in a practical circuit. For a Q of 12 and an antenna load of 50 ohms, this would represent a plate load resistance of 5075 ohms. If the plate load resistance in

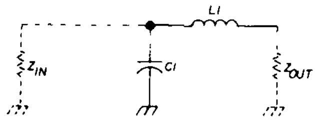

fig. 5. Typical step-down L network is highly efficient but very restrictive as far as acceptable Q is concerned.

a rf power amplifier is higher than 5075 ohms, a Q of more than 12 is required to retain the same level of harmonic suppression. This problem is circumvented by the use of the pi-L network, as discussed below.

pi-L network design

Another L network may be added to

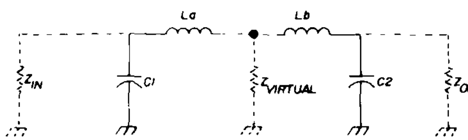

fig. 6. Pi network is basically two L networks in tandem.

the pi network as shown in **fig. 7** for additional harmonic attenuation. In actual practice C2 and C3 are combined into one capacitor so the circuit used in the transmitter is like that shown in **fig. 4**.

In the pi-L network, the input pi

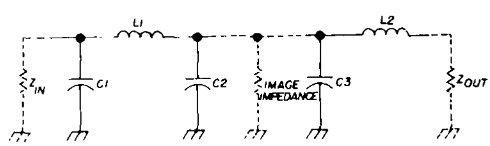

fig. 7. In the pi-L network a second L network is added to the basic pi network. Capacitors C2 and C3 are combined into one capacitor in a practical circuit, as shown in fig. 4.

section transforms the plate load impedance to some lower figure, such as 300 ohms; this is often called the *image* impedance. The final L network transforms the image impedance down to 50 ohms to match the antenna.

From **eq. 6** it can be seen that with an image impedance of 300 ohms and a Q of 12, the pi network has a maximum transformation of 43500 ohms. Using 70% of the *maximum* possible transformation as a practical maximum, as noted before, results in a maximum practical input impedance of 30500 ohms with a Q of 12. This is far in excess of what you will ever need in a power amplifier designed for amateur service.

The image impedance usually falls in the range between 200 and 400 ohms. It is selected for good harmonic attenuation, as well as balance in the T section of the pi-L network and reasonable component values for the capacitors and inductors. If the image impedance is too high, the tuning capacitor (C1) will be too small on 10 and 15 meters, and the two inductors will be very large. Large inductors, of course, increase circulating currents which result in higher losses due to heat.

table 1. Plate load impedances for different input power levels and different operating voltages and currents.

input power (W)	V	mA	plate impedance (ohms)
1000	2000	500	2546
2000	2000	1000	1273
2500	2000	1250	1019
1000	2500	400	3979
2000	2500	800	1989
2500	2500	1000	1592
1000	2800	357	4991
2000	2800	714	2496
2500	2800	893	1996
1000	3300	303	6933
2000	3300	606	3466
2500	3300	758	2773
1000	4000	250	10186
2000	4000	500	5093
2500	4000	625	4074
1000	5000	200	15915
2000	5000	400	7958
2500	5000	500	6366
1000	6000	167	22918
2000	6000	333	11459
2500	6000	417	9167

Q vs frequency

The loaded Q of a pi network (or any tank circuit, for that matter) is equal to its parallel-resonant impedance divided by either the inductive or capacitive reactance of the network. The resonant impedance because the pi network is designed to match the tube operating conditions.

$$Q_o = \frac{Z_p}{X} \quad (8)$$

The reactance of any inductor is directly proportional to frequency, increasing as the frequency increases. Therefore, from **eq. 8** it can be seen that if a particular inductor is used, loaded Q will vary inversely with frequency. As the frequency is lowered, for example, Q is raised a proportionate amount. With this in mind, it is easy to determine the Q for a given network on a different frequency from the following formula:

$$\frac{f1}{f2} \cong \frac{Q2}{Q1} \quad (9)$$

Where f1 and Q1 are the frequency and Q at one frequency, and f2 and Q2 are at the second, different frequency.

For example, if an 80-meter pi network has a Q of 12 at 4.0 MHz, what is the Q at 3.5 MHz?

$$\frac{4.0}{3.5} = \frac{Q2}{12} \qquad Q2 = 13.7$$

Although the actual loaded Q is somewhat dependent upon the value of plate load impedance used in the circuit, this approximation is accurate within 1%. In the above example, with a plate load impedance of 3000 ohms, Q2 would actually be 13.84.

Since the Q of the network goes up as

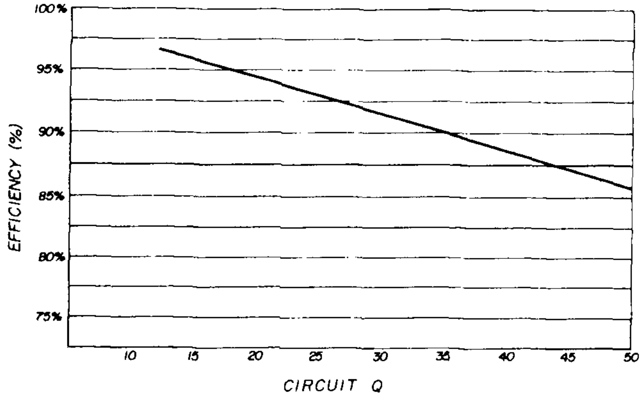

fig. 8. Efficiency of a network is inversely proportional to the loaded Q of the network.

the frequency goes down, it's a good idea to design the pi network for the highest frequency that is to be used.[2] With this approach, when the same inductor is used at lower frequencies within an amateur band, Q increases somewhat, improving harmonic attentuation.

Table 2 shows how Q varies as a pi network is retuned to a different frequency (same inductor). **Table 2A** shows a pi network designed for 4.0 MHz which is retuned to 3.5 MHz; Q increases from 12 at 4.0 MHz to 13.8 at 3.5 MHz. The values of the tuning and loading capacitors are shown for comparison.

Table 2B shows the case where a pi network is designed for 3.5 MHz with a Q of 12 and retuned to 4.0 MHz (same inductor). The Q drops to 10.4, well below the selected minimum of 12.

network efficiency

As the loaded Q of a network is increased, efficiency goes down because of higher circulating currents and higher losses in the components. Approximate efficiency is given by

$$\text{efficiency} = 100\left(1 - \frac{Q_o}{Q_u}\right) \qquad (10)$$

where Q_o is the loaded circuit Q, and Q_u is the unloaded component Q. The graph in **fig. 8** shows that efficiency is a linear function of loaded Q. For minimum loss, the loaded Q should be as low as convenient, while still providing adequate harmonic attenuation. This figure has arbitrarily been chosen as 12.

When the pi network is designed, the minimum Q of 12 can only be obtained at the upper frequency of each amateur band, and then only at the maximum input power level. For other frequencies or lower input powers, the loaded Q is higher than 12.

pi network design

Usually, when you are trying to design a pi network for your transmitter or linear amplifier, you must refer to graphs

table 2. Variations in Q as the resonant frequency of the pi network is changed (same inductor).

	frequency	plate impedance (ohms)	load impedance (ohms)	C1 (pF)	L1 (μH)	C2 (pF)	Q
A. Decreasing	4.0 MHz	2500	50	191	9.18	1097	12.0
frequency	3.5 MHz	2500	50	252	9.18	1536	13.8
B. Increasing	3.5 MHz	2500	50	218	10.49	1254	12.0
frequency	4.0 MHz	2500	50	165	10.49	863	10.4

table 3A. Pi network component values for matching a 50-ohm antenna load. Values have been chosen for a Q of 12 at the top edge of each amateur band. For plate load impedances greater than 5000 ohms, the Q of the network has been adjusted upward to compensate for the maximum transformation ratio, as discussed in the text. R1 is the plate load impedance.

R1 OHMS	F MHZ	C1 PF	L1 UH	C2 PF	R2 OHMS	'Q' QUAL.
200	3.5	3147	0.98	6244	50	13.8
200	7.0	1427	0.54	2827	50	12.6
200	14.0	701	0.27	1387	50	12.3
200	21.0	465	0.18	921	50	12.3
200	29.7	322	0.13	636	50	12.0
300	3.5	2098	1.38	5071	50	13.8
300	7.0	952	0.76	2294	50	12.6
300	14.0	467	0.39	1125	50	12.3
300	21.0	310	0.26	747	50	12.3
300	29.7	214	0.19	516	50	12.0
400	3.5	1573	1.76	4368	50	13.8
400	7.0	714	0.97	1975	50	12.6
400	14.0	350	0.49	968	50	12.3
400	21.0	233	0.33	643	50	12.3
400	29.7	161	0.24	444	50	12.0
500	3.5	1259	2.14	3886	50	13.8
500	7.0	571	1.18	1755	50	12.6
500	14.0	280	0.60	859	50	12.3
500	21.0	186	0.40	571	50	12.3
500	29.7	129	0.29	394	50	12.0
600	3.5	1049	2.51	3528	50	13.8
600	7.0	476	1.38	1590	50	12.6
600	14.0	234	0.70	779	50	12.3
600	21.0	155	0.47	517	50	12.3
600	29.7	107	0.34	357	50	12.0
700	3.5	899	2.88	3248	50	13.8
700	7.0	408	1.58	1462	50	12.6
700	14.0	200	0.81	716	50	12.3
700	21.0	133	0.54	475	50	12.3
700	29.7	92	0.39	328	50	12.0
800	3.5	787	3.24	3021	50	13.8
800	7.0	357	1.78	1358	50	12.6
800	14.0	175	0.91	665	50	12.3
800	21.0	116	0.61	442	50	12.3
800	29.7	80	0.44	304	50	12.0
900	3.5	699	3.60	2832	50	13.8
900	7.0	317	1.98	1271	50	12.6
900	14.0	156	1.01	622	50	12.3
900	21.0	103	0.67	413	50	12.3
900	29.7	71	0.49	285	50	12.0
1000	3.5	629	3.96	2671	50	13.8
1000	7.0	285	2.18	1197	50	12.6
1000	14.0	140	1.11	586	50	12.3
1000	21.0	93	0.74	389	50	12.3
1000	29.7	64	0.54	268	50	12.0
1100	3.5	572	4.32	2532	50	13.8
1100	7.0	260	2.37	1133	50	12.6
1100	14.0	127	1.21	555	50	12.3
1100	21.0	85	0.81	368	50	12.3
1100	29.7	58	0.58	253	50	12.0
1200	3.5	524	4.67	2410	50	13.8
1200	7.0	238	2.57	1077	50	12.6
1200	14.0	117	1.31	527	50	12.3
1200	21.0	78	0.87	350	50	12.3
1200	29.7	54	0.63	241	50	12.0
1300	3.5	484	5.03	2302	50	13.8
1300	7.0	220	2.76	1027	50	12.6
1300	14.0	108	1.40	502	50	12.3
1300	21.0	72	0.94	333	50	12.3
1300	29.7	49	0.68	229	50	12.0
1400	3.5	450	5.38	2205	50	13.8
1400	7.0	204	2.95	982	50	12.6
1400	14.0	100	1.50	480	50	12.3
1400	21.0	66	1.01	319	50	12.3
1400	29.7	46	0.73	219	50	12.0
1500	3.5	420	5.73	2117	50	13.8
1500	7.0	190	3.14	942	50	12.6
1500	14.0	93	1.60	460	50	12.3
1500	21.0	62	1.07	305	50	12.3
1500	29.7	43	0.77	210	50	12.0
2000	3.5	315	7.46	1776	50	13.8
2000	7.0	143	4.09	783	50	12.6
2000	14.0	70	2.08	382	50	12.3
2000	21.0	47	1.39	253	50	12.3
2000	29.7	32	1.01	174	50	12.0
2500	3.5	252	9.17	1536	50	13.8
2500	7.0	114	5.03	670	50	12.6
2500	14.0	56	2.56	326	50	12.3
2500	21.0	37	1.71	216	50	12.3
2500	29.7	26	1.24	148	50	12.0
3000	3.5	210	10.86	1352	50	13.8
3000	7.0	95	5.95	583	50	12.6
3000	14.0	47	3.03	283	50	12.3
3000	21.0	31	2.02	187	50	12.3
3000	29.7	21	1.46	128	50	12.0
3500	3.5	180	12.53	1203	50	13.8
3500	7.0	82	6.86	512	50	12.6
3500	14.0	40	3.49	247	50	12.3
3500	21.0	27	2.34	164	50	12.3
3500	29.7	18	1.69	111	50	12.0
4000	3.5	157	14.19	1079	50	13.8
4000	7.0	71	7.77	451	50	12.6
4000	14.0	35	3.95	217	50	12.3
4000	21.0	23	2.64	144	50	12.3
4000	29.7	16	1.91	97	50	12.0
4500	3.5	140	15.84	971	50	13.8
4500	7.0	63	8.66	397	50	12.6
4500	14.0	31	4.40	190	50	12.3
4500	21.0	21	2.95	126	50	12.3
4500	29.7	14	2.13	84	50	12.0
5000	3.5	126	17.48	875	50	13.8
5000	7.0	57	9.55	348	50	12.6
5000	14.0	28	4.85	165	50	12.3
5000	21.0	19	3.25	109	50	12.3
5000	29.7	13	2.34	72	50	12.0
5500	3.5	119	18.41	861	50	14.4
5500	7.0	54	10.05	341	50	13.1
5500	14.0	27	5.11	162	50	12.8
5500	21.0	18	3.42	107	50	12.8
5500	29.7	12	2.47	70	50	12.5
6000	3.5	114	19.18	862	50	15.1
6000	7.0	52	10.48	341	50	13.7
6000	14.0	25	5.33	162	50	13.4
6000	21.0	17	3.56	107	50	13.4
6000	29.7	12	2.57	70	50	13.1
6500	3.5	110	19.92	862	50	15.7
6500	7.0	50	10.89	341	50	14.2
6500	14.0	24	5.54	162	50	14.0
6500	21.0	16	3.70	107	50	13.9
6500	29.7	11	2.67	70	50	13.6
7000	3.5	106	20.63	862	50	16.3
7000	7.0	48	11.28	341	50	14.8
7000	14.0	24	5.74	162	50	14.5
7000	21.0	16	3.84	107	50	14.4
7000	29.7	11	2.77	70	50	14.1
7500	3.5	102	21.31	862	50	16.8
7500	7.0	46	11.66	341	50	15.3
7500	14.0	23	5.93	162	50	15.0
7500	21.0	15	3.97	107	50	14.9
7500	29.7	10	2.86	70	50	14.6
8000	3.5	99	21.98	862	50	17.4
8000	7.0	45	12.02	341	50	15.8
8000	14.0	22	6.11	162	50	15.5
8000	21.0	15	4.09	107	50	15.4
8000	29.7	10	2.95	70	50	15.1
8500	3.5	96	22.62	862	50	17.9
8500	7.0	44	12.38	341	50	16.3
8500	14.0	21	6.29	162	50	16.0
8500	21.0	14	4.21	107	50	15.9
8500	29.7	10	3.04	70	50	15.6
9000	3.5	93	23.24	862	50	18.5
9000	7.0	42	12.72	341	50	16.7
9000	14.0	21	6.47	162	50	16.4
9000	21.0	14	4.33	107	50	16.4
9000	29.7	10	3.12	70	50	16.0
9500	3.5	91	23.85	862	50	19.0
9500	7.0	41	13.06	341	50	17.2
9500	14.0	20	6.64	162	50	16.9
9500	21.0	13	4.44	107	50	16.8
9500	29.7	9	3.21	70	50	16.4
10000	3.5	88	24.44	862	50	19.5
10000	7.0	40	13.38	341	50	17.7
10000	14.0	20	6.81	162	50	17.3
10000	21.0	13	4.55	107	50	17.3
10000	29.7	9	3.29	70	50	16.9
10500	3.5	86	25.02	862	50	19.9
10500	7.0	39	13.70	341	50	18.1
10500	14.0	19	6.97	162	50	17.8
10500	21.0	13	4.66	107	50	17.7
10500	29.7	9	3.37	70	50	17.3
11000	3.5	84	25.58	862	50	20.4
11000	7.0	38	14.01	341	50	18.5
11000	14.0	19	7.13	162	50	18.2
11000	21.0	12	4.77	107	50	18.1
11000	29.7	9	3.44	70	50	17.7
11500	3.5	83	26.13	862	50	20.9
11500	7.0	37	14.32	341	50	18.9
11500	14.0	18	7.28	162	50	18.6
11500	21.0	12	4.87	107	50	18.5
11500	29.7	8	3.52	70	50	18.1
12000	3.5	81	26.67	862	50	21.3
12000	7.0	37	14.61	341	50	19.3
12000	14.0	18	7.43	162	50	19.0
12000	21.0	12	4.97	107	50	18.9
12000	29.7	8	3.59	70	50	18.5

shown in reference books such as the ARRL "Radio Amateur's Handbook."[3]

These graphs are often somewhat confusing because you must first determine the

table 3B. Pi-network component values for use within the 160-meter amateur band. Values were determined as in table 3A.

R1 OHMS	F MHZ	C1 PF	L1 UH	C2 PF	R2 OHMS	'Q' QUAL.
1000	1.8	1187	7.94	5019	50	13.4
1000	1.9	1062	7.95	4459	50	12.7
1000	2.0	955	7.96	3979	50	12.0
1250	1.8	949	9.71	4419	50	13.4
1250	1.9	849	9.72	3917	50	12.7
1250	2.0	764	9.74	3487	50	12.0
1500	1.8	791	11.47	3969	50	13.4
1500	1.9	708	11.48	3510	50	12.7
1500	2.0	637	11.49	3116	50	12.0
1750	1.8	678	13.21	3613	50	13.4
1750	1.9	607	13.22	3197	50	12.7
1750	2.0	546	13.23	2822	50	12.0
2000	1.8	593	14.94	3322	50	13.4
2000	1.9	531	14.94	2922	50	12.7
2000	2.0	477	14.95	2579	50	12.0
2250	1.8	527	16.65	3076	50	13.4
2250	1.9	472	16.65	2697	50	12.7
2250	2.0	424	16.66	2373	50	12.0
2500	1.8	475	18.36	2864	50	13.4
2500	1.9	425	18.36	2504	50	12.7
2500	2.0	382	18.36	2194	50	12.0
2750	1.8	432	20.05	2678	50	13.4
2750	1.9	386	20.05	2333	50	12.7
2750	2.0	347	20.04	2036	50	12.0
3000	1.8	396	21.74	2513	50	13.4
3000	1.9	354	21.73	2181	50	12.7
3000	2.0	318	21.72	1894	50	12.0
3250	1.8	365	23.41	2364	50	13.4
3250	1.9	327	23.40	2043	50	12.7
3250	2.0	294	23.38	1766	50	12.0
3500	1.8	339	25.08	2229	50	13.4
3500	1.9	303	25.06	1917	50	12.7
3500	2.0	273	25.04	1647	50	12.0
3750	1.8	316	26.75	2104	50	13.4
3750	1.9	283	26.72	1801	50	12.7
3750	2.0	255	26.68	1538	50	12.0
4000	1.8	297	28.40	1988	50	13.4
4000	1.9	265	28.37	1693	50	12.7
4000	2.0	239	28.32	1435	50	12.0
4250	1.8	279	30.05	1881	50	13.4
4250	1.9	250	30.00	1591	50	12.7
4250	2.0	225	29.95	1337	50	12.0
4500	1.8	264	31.69	1779	50	13.4
4500	1.9	236	31.64	1495	50	12.7
4500	2.0	212	31.57	1244	50	12.0
4750	1.8	250	33.33	1684	50	13.4
4750	1.9	224	33.26	1403	50	12.7
4750	2.0	201	33.17	1155	50	12.0
5000	1.8	237	34.96	1593	50	13.4
5000	1.9	212	34.87	1315	50	12.7
5000	2.0	191	34.77	1058	50	12.0
5250	1.8	230	36.01	1566	50	13.7
5250	1.9	206	35.93	1290	50	12.9
5250	2.0	185	35.82	1042	50	12.2
5500	1.8	225	36.81	1566	50	14.0
5500	1.9	201	36.73	1290	50	13.2
5500	2.0	181	36.63	1042	50	12.5
5750	1.8	220	37.59	1567	50	14.3
5750	1.9	197	37.52	1290	50	13.5
5750	2.0	177	37.41	1042	50	12.8
6000	1.8	215	38.36	1567	50	14.6
6000	1.9	193	38.28	1290	50	13.8
6000	2.0	173	38.18	1042	50	13.1
6250	1.8	211	39.11	1567	50	14.9
6250	1.9	189	39.03	1290	50	14.1
6250	2.0	170	38.94	1042	50	13.3
6500	1.8	207	39.84	1567	50	15.2
6500	1.9	185	39.77	1290	50	14.4
6500	2.0	166	39.68	1042	50	13.6
6750	1.8	203	40.56	1567	50	15.5
6750	1.9	182	40.49	1290	50	14.6
6750	2.0	163	40.40	1042	50	13.9
7000	1.8	199	41.27	1567	50	15.8
7000	1.9	178	41.20	1290	50	14.9
7000	2.0	160	41.11	1042	50	14.1
7250	1.8	196	41.96	1567	50	16.1
7250	1.9	175	41.90	1290	50	15.2
7250	2.0	158	41.81	1042	50	14.4
7500	1.8	193	42.64	1567	50	16.3
7500	1.9	172	42.58	1290	50	15.4
7500	2.0	155	42.50	1042	50	14.6
7750	1.8	189	43.31	1567	50	16.6
7750	1.9	169	43.25	1290	50	15.7
7750	2.0	152	43.17	1042	50	14.8
8000	1.8	186	43.97	1567	50	16.9
8000	1.9	167	43.92	1290	50	15.9
8000	2.0	150	43.84	1042	50	15.1
8250	1.8	184	44.62	1567	50	17.1
8250	1.9	164	44.57	1290	50	16.2
8250	2.0	148	44.49	1042	50	15.3
8500	1.8	181	45.26	1567	50	17.4
8500	1.9	162	45.21	1290	50	16.4
8500	2.0	146	45.14	1042	50	15.6
8750	1.8	178	45.89	1567	50	17.6
8750	1.9	160	45.84	1290	50	16.7
8750	2.0	144	45.77	1042	50	15.8
9000	1.8	176	46.51	1567	50	17.9
9000	1.9	157	46.47	1290	50	16.9
9000	2.0	142	46.40	1042	50	16.0
9250	1.8	173	47.13	1567	50	18.1
9250	1.9	155	47.08	1290	50	17.1
9250	2.0	140	47.02	1042	50	16.2
9500	1.8	171	47.73	1567	50	18.4
9500	1.9	153	47.69	1290	50	17.4
9500	2.0	138	47.63	1042	50	16.4
9750	1.8	169	48.33	1567	50	18.6
9750	1.9	151	48.29	1290	50	17.6
9750	2.0	136	48.23	1042	50	16.7
10000	1.8	167	48.92	1568	50	18.9
10000	1.9	149	48.88	1290	50	17.8
10000	2.0	134	48.82	1042	50	16.9
10250	1.8	165	49.50	1568	50	19.1
10250	1.9	147	49.46	1290	50	18.0
10250	2.0	133	49.41	1042	50	17.1
10500	1.8	163	50.07	1568	50	19.3
10500	1.9	146	50.04	1290	50	18.3
10500	2.0	131	49.98	1042	50	17.3
10750	1.8	161	50.64	1568	50	19.6
10750	1.9	144	50.61	1290	50	18.5
10750	2.0	130	50.56	1042	50	17.5
11000	1.8	159	51.20	1568	50	19.8
11000	1.9	142	51.17	1290	50	18.7
11000	2.0	128	51.12	1042	50	17.7
11250	1.8	157	51.76	1568	50	20.0
11250	1.9	141	51.73	1290	50	18.9
11250	2.0	127	51.68	1042	50	17.9
11500	1.8	156	52.30	1568	50	20.2
11500	1.9	139	52.28	1290	50	19.1
11500	2.0	125	52.23	1042	50	18.1
11750	1.8	154	52.85	1568	50	20.5
11750	1.9	138	52.82	1290	50	19.3
11750	2.0	124	52.78	1042	50	18.3
12000	1.8	152	53.38	1568	50	20.7
12000	1.9	136	53.36	1290	50	19.5
12000	2.0	123	53.32	1042	50	18.5

plate load impedance, select a value of Q, and then find the reactance of each of the components. Then you must locate yet another graph to convert these reactance values into actual values of inductance and capacitance.

Few of these charts and graphs are extended above plate load impedances of 5000 ohms, and most give vague reference to the fact that if the plate load impedance is greater than about 5000 ohms, the Q should be increased.

The charts in **table 3** and **table 4** are computer derived and offer all the required information to build a practical pi network. The pi networks in **table 3** for plate load impedances above 5000 ohms have increasing Q so that the transformation ratio never exceeds the 70% maximum. *In addition, the inductors chosen for each of the designs are calculated for the highest frequency in the band.*

table 4A. Pi-L network component values for matching a 50-ohm antenna load. Values have been chosen for a Q of 12 at the top edge of each amateur band. The image impedance (R3) has been chosen to provide a balanced transformation in the T section of the pi-L network. R1 is the plate load impedance.

R1 OHMS	F MHZ	C1 PF.	L1 UH.	C2 PF.	L2 UH.	R3 OHMS	R2 OHMS	'Q' QUAL.
500	3.5	1219	2.86	1749	4.45	241	50	13.4
500	7.0	565	1.59	753	2.44	280	50	12.4
500	14.0	277	0.81	365	1.24	288	50	12.2
500	21.0	185	0.54	243	0.83	288	50	12.2
500	29.7	129	0.39	166	0.60	300	50	12.0
600	3.5	1015	3.30	1595	4.45	241	50	13.4
600	7.0	471	1.83	686	2.44	280	50	12.4
600	14.0	231	0.94	332	1.24	288	50	12.2
600	21.0	154	0.63	222	0.83	288	50	12.2
600	29.7	107	0.45	151	0.60	300	50	12.0
700	3.5	870	3.74	1475	4.45	241	50	13.4
700	7.0	403	2.07	635	2.44	280	50	12.4
700	14.0	198	1.06	307	1.24	288	50	12.2
700	21.0	132	0.71	205	0.83	288	50	12.2
700	29.7	92	0.51	140	0.60	300	50	12.0
800	3.5	762	4.17	1378	4.45	241	50	13.4
800	7.0	353	2.31	593	2.44	280	50	12.4
800	14.0	173	1.18	287	1.24	288	50	12.2
800	21.0	116	0.79	191	0.83	288	50	12.2
800	29.7	80	0.57	130	0.60	300	50	12.0
900	3.5	677	4.60	1297	4.45	241	50	13.4
900	7.0	314	2.54	558	2.44	280	50	12.4
900	14.0	154	1.30	270	1.24	288	50	12.2
900	21.0	103	0.87	180	0.83	288	50	12.2
900	29.7	71	0.63	123	0.60	300	50	12.0
1000	3.5	609	5.02	1229	4.45	241	50	13.4
1000	7.0	282	2.77	529	2.44	280	50	12.4
1000	14.0	139	1.42	256	1.24	288	50	12.2
1000	21.0	92	0.95	171	0.83	288	50	12.2
1000	29.7	64	0.68	116	0.60	300	50	12.0
1100	3.5	554	5.43	1171	4.45	241	50	13.4
1100	7.0	257	3.00	504	2.44	280	50	12.4
1100	14.0	126	1.53	244	1.24	288	50	12.2
1100	21.0	84	1.02	163	0.83	288	50	12.2
1100	29.7	58	0.74	111	0.60	300	50	12.0
1200	3.5	508	5.85	1120	4.45	241	50	13.4
1200	7.0	235	3.23	482	2.44	280	50	12.4
1200	14.0	116	1.65	233	1.24	288	50	12.2
1200	21.0	77	1.10	156	0.83	288	50	12.2
1200	29.7	54	0.80	106	0.60	300	50	12.0
1300	3.5	469	6.25	1075	4.45	241	50	13.4
1300	7.0	217	3.45	462	2.44	280	50	12.4
1300	14.0	107	1.76	224	1.24	288	50	12.2
1300	21.0	71	1.18	149	0.83	288	50	12.2
1300	29.7	49	0.85	102	0.60	300	50	12.0
1400	3.5	435	6.66	1034	4.45	241	50	13.4
1400	7.0	202	3.67	445	2.44	280	50	12.4
1400	14.0	99	1.88	216	1.24	288	50	12.2
1400	21.0	66	1.25	144	0.83	288	50	12.2
1400	29.7	46	0.90	98	0.60	300	50	12.0
1500	3.5	406	7.06	998	4.45	241	50	13.4
1500	7.0	188	3.89	430	2.44	280	50	12.4
1500	14.0	92	1.99	208	1.24	288	50	12.2
1500	21.0	62	1.33	139	0.83	288	50	12.2
1500	29.7	43	0.96	95	0.60	300	50	12.0
2000	3.5	305	9.05	859	4.45	241	50	13.4
2000	7.0	141	4.97	370	2.44	280	50	12.4
2000	14.0	69	2.54	179	1.24	288	50	12.2
2000	21.0	46	1.69	119	0.83	288	50	12.2
2000	29.7	32	1.22	81	0.60	300	50	12.0
2500	3.5	244	10.99	764	4.45	241	50	13.4
2500	7.0	113	6.03	329	2.44	280	50	12.4
2500	14.0	55	3.08	159	1.24	288	50	12.2
2500	21.0	37	2.05	106	0.83	288	50	12.2
2500	29.7	26	1.48	72	0.60	300	50	12.0
3000	3.5	203	12.90	693	4.45	241	50	13.4
3000	7.0	94	7.07	298	2.44	280	50	12.4
3000	14.0	46	3.61	144	1.24	288	50	12.2
3000	21.0	31	2.41	96	0.83	288	50	12.2
3000	29.7	21	1.74	66	0.60	300	50	12.0
3500	3.5	174	14.79	638	4.45	241	50	13.4
3500	7.0	81	8.10	274	2.44	280	50	12.4
3500	14.0	40	4.13	133	1.24	288	50	12.2
3500	21.0	26	2.76	89	0.83	288	50	12.2
3500	29.7	18	1.99	60	0.60	300	50	12.0
4000	3.5	152	16.67	593	4.45	241	50	13.4
4000	7.0	71	9.12	255	2.44	280	50	12.4
4000	14.0	35	4.65	123	1.24	288	50	12.2
4000	21.0	23	3.10	82	0.83	288	50	12.2
4000	29.7	16	2.24	56	0.60	300	50	12.0
4500	3.5	135	18.53	555	4.45	241	50	13.4
4500	7.0	63	10.12	239	2.44	280	50	12.4
4500	14.0	31	5.17	116	1.24	288	50	12.2
4500	21.0	21	3.44	77	0.83	288	50	12.2
4500	29.7	14	2.49	53	0.60	300	50	12.0
5000	3.5	122	20.37	523	4.45	241	50	13.4
5000	7.0	56	11.13	225	2.44	280	50	12.4
5000	14.0	28	5.68	109	1.24	288	50	12.2
5000	21.0	18	3.78	73	0.83	288	50	12.2
5000	29.7	13	2.73	50	0.60	300	50	12.0
5500	3.5	111	22.21	496	4.45	241	50	13.4
5500	7.0	51	12.12	213	2.44	280	50	12.4
5500	14.0	25	6.18	103	1.24	288	50	12.2
5500	21.0	17	4.12	69	0.83	288	50	12.2
5500	29.7	12	2.97	47	0.60	300	50	12.0
6000	3.5	102	24.03	472	4.45	241	50	13.4
6000	7.0	47	13.11	203	2.44	280	50	12.4
6000	14.0	23	6.69	98	1.24	288	50	12.2
6000	21.0	15	4.46	65	0.83	288	50	12.2
6000	29.7	11	3.22	45	0.60	300	50	12.0
6500	3.5	94	25.85	450	4.45	241	50	13.4
6500	7.0	43	14.09	194	2.44	280	50	12.4
6500	14.0	21	7.19	94	1.24	288	50	12.2
6500	21.0	14	4.79	62	0.83	288	50	12.2
6500	29.7	10	3.46	43	0.60	300	50	12.0
7000	3.5	87	27.65	431	4.45	241	50	13.4
7000	7.0	40	15.07	185	2.44	280	50	12.4
7000	14.0	20	7.69	90	1.24	288	50	12.2
7000	21.0	13	5.12	60	0.83	288	50	12.2
7000	29.7	9	3.70	41	0.60	300	50	12.0
7500	3.5	81	29.45	413	4.45	241	50	13.4
7500	7.0	38	16.05	178	2.44	280	50	12.4
7500	14.0	18	8.18	86	1.24	288	50	12.2
7500	21.0	12	5.45	57	0.83	288	50	12.2
7500	29.7	9	3.93	39	0.60	300	50	12.0
8000	3.5	76	31.25	397	4.45	241	50	13.4
8000	7.0	35	17.02	171	2.44	280	50	12.4
8000	14.0	17	8.68	83	1.24	288	50	12.2
8000	21.0	12	5.78	55	0.83	288	50	12.2
8000	29.7	8	4.17	38	0.60	300	50	12.0
8500	3.5	72	33.03	383	4.45	241	50	13.4
8500	7.0	33	17.99	165	2.44	280	50	12.4
8500	14.0	16	9.17	80	1.24	288	50	12.2
8500	21.0	11	6.11	53	0.83	288	50	12.2
8500	29.7	8	4.41	36	0.60	300	50	12.0
9000	3.5	68	34.82	369	4.45	241	50	13.4
9000	7.0	31	18.95	159	2.44	280	50	12.4
9000	14.0	15	9.66	77	1.24	288	50	12.2
9000	21.0	10	6.44	51	0.83	288	50	12.2
9000	29.7	7	4.64	35	0.60	300	50	12.0
9500	3.5	64	36.59	357	4.45	241	50	13.4
9500	7.0	30	19.91	154	2.44	280	50	12.4
9500	14.0	15	10.15	74	1.24	288	50	12.2
9500	21.0	10	6.77	50	0.83	288	50	12.2
9500	29.7	7	4.88	34	0.60	300	50	12.0
10000	3.5	61	38.36	345	4.45	241	50	13.4
10000	7.0	28	20.87	149	2.44	280	50	12.4
10000	14.0	14	10.64	72	1.24	288	50	12.2
10000	21.0	9	7.09	48	0.83	288	50	12.2
10000	29.7	6	5.11	33	0.60	300	50	12.0
10500	3.5	58	40.13	334	4.45	241	50	13.4
10500	7.0	27	21.82	144	2.44	280	50	12.4
10500	14.0	13	11.12	70	1.24	288	50	12.2
10500	21.0	9	7.42	46	0.83	288	50	12.2
10500	29.7	6	5.34	32	0.60	300	50	12.0
11000	3.5	55	41.89	324	4.45	241	50	13.4
11000	7.0	26	22.78	140	2.44	280	50	12.4
11000	14.0	13	11.61	67	1.24	288	50	12.2
11000	21.0	8	7.74	45	0.83	288	50	12.2
11000	29.7	6	5.58	31	0.60	300	50	12.0
11500	3.5	53	43.65	315	4.45	241	50	13.4
11500	7.0	25	23.73	135	2.44	280	50	12.4
11500	14.0	12	12.09	65	1.24	288	50	12.2
11500	21.0	8	8.06	44	0.83	288	50	12.2
11500	29.7	6	5.81	30	0.60	300	50	12.0
12000	3.5	51	45.40	306	4.45	241	50	13.4
12000	7.0	24	24.67	131	2.44	280	50	12.4
12000	14.0	12	12.57	64	1.24	288	50	12.2
12000	21.0	8	8.38	42	0.83	288	50	12.2
12000	29.7	5	6.04	29	0.60	300	50	12.0

The Q of the network at the highest frequency is 12 except when the plate load impedance is greater than 5075 ohms. The chart shows the capacitance values required to resonate the network to the lowest frequency in the band (maximum capacitance), as well as the operating Q at that frequency. In **table 4**, the image impedance (R3) at the lower frequency is also given.

table 4B. Pi-L network compenent values for the 160-meter amateur band. Values were determined as in table 4A.

A suitable coil for the L-network inductor consists of two inches of Air-Dux 1606T (6 turns-per-inch, no. 14 wire, 2" diameter). This inductor should be placed at right angles to the main pi inductor to avoid mutual inductance. In the following chart, 7.125 would be slightly over 7 full turns, 2.875 is slightly less than 3 *full turns.*

band	turns	approximate inductance
80	11.000	4.43 μH
40	7.125	2.43 μH
20	4.5000	1.23 μH
15	3.500	0.83 μH
10	2.875	0.60 μH

R1 OHMS	F MHZ	C1 PF.	L1 UH.	C2 PF.	L2 UH.	R3 OHMS	R2 OHMS	'Q' QUAL.
1000	1.8	1155	10.08	2279	8.90	252	50	13.1
1000	1.9	1047	10.12	1978	8.90	275	50	12.5
1000	2.0	955	10.16	1729	8.90	300	50	12.0
1250	1.8	924	12.14	2033	8.90	252	50	13.1
1250	1.9	838	12.18	1764	8.90	275	50	12.5
1250	2.0	764	12.22	1542	8.90	300	50	12.0
1500	1.8	770	14.17	1850	8.90	252	50	13.1
1500	1.9	698	14.20	1606	8.90	275	50	12.5
1500	2.0	637	14.23	1404	8.90	300	50	12.0
1750	1.8	660	16.17	1708	8.90	252	50	13.1
1750	1.9	599	16.19	1482	8.90	275	50	12.5
1750	2.0	546	16.22	1296	8.90	300	50	12.0
2000	1.8	578	18.14	1593	8.90	252	50	13.1
2000	1.9	524	18.15	1382	8.90	275	50	12.5
2000	2.0	477	18.17	1208	8.90	300	50	12.0
2250	1.8	514	20.09	1497	8.90	252	50	13.1
2250	1.9	466	20.10	1299	8.90	275	50	12.5
2250	2.0	424	20.11	1136	8.90	300	50	12.0
2500	1.8	462	22.02	1416	8.90	252	50	13.1
2500	1.9	419	22.02	1229	8.90	275	50	12.5
2500	2.0	382	22.02	1074	8.90	300	50	12.0
2750	1.8	420	23.94	1346	8.90	252	50	13.1
2750	1.9	381	23.93	1168	8.90	275	50	12.5
2750	2.0	347	23.92	1021	8.90	300	50	12.0
3000	1.8	385	25.85	1285	8.90	252	50	13.1
3000	1.9	349	25.83	1115	8.90	275	50	12.5
3000	2.0	318	25.81	975	8.90	300	50	12.0
3250	1.8	356	27.74	1230	8.90	252	50	13.1
3250	1.9	322	27.71	1068	8.90	275	50	12.5
3250	2.0	294	27.68	933	8.90	300	50	12.0
3500	1.8	330	29.62	1182	8.90	252	50	13.1
3500	1.9	299	29.58	1026	8.90	275	50	12.5
3500	2.0	273	29.54	897	8.90	300	50	12.0
3750	1.8	308	31.50	1138	8.90	252	50	13.1
3750	1.9	279	31.45	988	8.90	275	50	12.5
3750	2.0	255	31.40	864	8.90	300	50	12.0
4000	1.8	289	33.37	1099	8.90	252	50	13.1
4000	1.9	262	33.30	954	8.90	275	50	12.5
4000	2.0	239	33.24	834	8.90	300	50	12.0
4250	1.8	272	35.23	1062	8.90	252	50	13.1
4250	1.9	246	35.15	922	8.90	275	50	12.5
4250	2.0	225	35.08	806	8.90	300	50	12.0
4500	1.8	257	37.08	1029	8.90	252	50	13.1
4500	1.9	233	36.99	893	8.90	275	50	12.5
4500	2.0	212	36.91	781	8.90	300	50	12.0
4750	1.8	243	38.92	999	8.90	252	50	13.1
4750	1.9	221	38.83	867	8.90	275	50	12.5
4750	2.0	201	38.73	758	8.90	300	50	12.0
5000	1.8	231	40.76	970	8.90	252	50	13.1
5000	1.9	209	40.65	842	8.90	275	50	12.5
5000	2.0	191	40.54	736	8.90	300	50	12.0
5250	1.8	220	42.60	944	8.90	252	50	13.1
5250	1.9	200	42.47	819	8.90	275	50	12.5
5250	2.0	182	42.35	716	8.90	300	50	12.0
5500	1.8	210	44.43	919	8.90	252	50	13.1
5500	1.9	190	44.29	798	8.90	275	50	12.5
5500	2.0	174	44.16	697	8.90	300	50	12.0
5750	1.8	201	46.25	896	8.90	252	50	13.1
5750	1.9	182	46.10	777	8.90	275	50	12.5
5750	2.0	166	45.95	680	8.90	300	50	12.0
6000	1.8	193	48.07	874	8.90	252	50	13.1
6000	1.9	175	47.91	759	8.90	275	50	12.5
6000	2.0	159	47.75	663	8.90	300	50	12.0
6250	1.8	185	49.88	853	8.90	252	50	13.1
6250	1.9	168	49.71	741	8.90	275	50	12.5
6250	2.0	153	49.53	648	8.90	300	50	12.0
6500	1.8	178	51.69	834	8.90	252	50	13.1
6500	1.9	161	51.50	724	8.90	275	50	12.5
6500	2.0	147	51.32	633	8.90	300	50	12.0
6750	1.8	171	53.50	816	8.90	252	50	13.1
6750	1.9	155	53.30	708	8.90	275	50	12.5
6750	2.0	141	53.10	619	8.90	300	50	12.0
7000	1.8	165	55.30	798	8.90	252	50	13.1
7000	1.9	150	55.09	693	8.90	275	50	12.5
7000	2.0	136	54.87	606	8.90	300	50	12.0
7250	1.8	159	57.10	782	8.90	252	50	13.1
7250	1.9	144	56.87	678	8.90	275	50	12.5
7250	2.0	132	56.64	593	8.90	300	50	12.0
7500	1.8	154	58.89	766	8.90	252	50	13.1
7500	1.9	140	58.65	665	8.90	275	50	12.5
7500	2.0	127	58.41	581	8.90	300	50	12.0
7750	1.8	149	60.69	751	8.90	252	50	13.1
7750	1.9	135	60.43	652	8.90	275	50	12.5
7750	2.0	123	60.17	570	8.90	300	50	12.0
8000	1.8	144	62.47	736	8.90	252	50	13.1
8000	1.9	131	62.20	639	8.90	275	50	12.5
8000	2.0	119	61.93	559	8.90	300	50	12.0
8250	1.8	140	64.26	723	8.90	252	50	13.1
8250	1.9	127	63.97	627	8.90	275	50	12.5
8250	2.0	116	63.69	548	8.90	300	50	12.0
8500	1.8	136	66.04	709	8.90	252	50	13.1
8500	1.9	123	65.74	616	8.90	275	50	12.5
8500	2.0	112	65.44	538	8.90	300	50	12.0
8750	1.8	132	67.82	697	8.90	252	50	13.1
8750	1.9	120	67.50	605	8.90	275	50	12.5
8750	2.0	109	67.19	529	8.90	300	50	12.0
9000	1.8	128	69.59	684	8.90	252	50	13.1
9000	1.9	116	69.27	594	8.90	275	50	12.5
9000	2.0	106	68.94	519	8.90	300	50	12.0
9250	1.8	125	71.37	673	8.90	252	50	13.1
9250	1.9	113	71.02	584	8.90	275	50	12.5
9250	2.0	103	70.69	510	8.90	300	50	12.0
9500	1.8	122	73.14	661	8.90	252	50	13.1
9500	1.9	110	72.78	574	8.90	275	50	12.5
9500	2.0	101	72.43	502	8.90	300	50	12.0
9750	1.8	119	74.91	650	8.90	252	50	13.1
9750	1.9	107	74.53	564	8.90	275	50	12.5
9750	2.0	98	74.17	494	8.90	300	50	12.0
10000	1.8	116	76.67	640	8.90	252	50	13.1
10000	1.9	105	76.28	555	8.90	275	50	12.5
10000	2.0	95	75.90	486	8.90	300	50	12.0
10250	1.8	113	78.43	629	8.90	252	50	13.1
10250	1.9	102	78.03	546	8.90	275	50	12.5
10250	2.0	93	77.64	478	8.90	300	50	12.0
10500	1.8	110	80.19	620	8.90	252	50	13.1
10500	1.9	100	79.78	538	8.90	275	50	12.5
10500	2.0	91	79.37	470	8.90	300	50	12.0
10750	1.8	107	81.95	610	8.90	252	50	13.1
10750	1.9	97	81.52	529	8.90	275	50	12.5
10750	2.0	89	81.09	463	8.90	300	50	12.0
11000	1.8	105	83.71	601	8.90	252	50	13.1
11000	1.9	95	83.26	521	8.90	275	50	12.5
11000	2.0	87	82.82	456	8.90	300	50	12.0
11250	1.8	103	85.46	592	8.90	252	50	13.1
11250	1.9	93	85.00	514	8.90	275	50	12.5
11250	2.0	85	84.54	449	8.90	300	50	12.0
11500	1.8	100	87.21	583	8.90	252	50	13.1
11500	1.9	91	86.73	506	8.90	275	50	12.5
11500	2.0	83	86.26	442	8.90	300	50	12.0
11750	1.8	98	88.96	574	8.90	252	50	13.1
11750	1.9	89	88.47	499	8.90	275	50	12.5
11750	2.0	91	87.98	436	8.90	300	50	12.0
12000	1.8	96	90.71	566	8.90	252	50	13.1
12000	1.9	87	90.20	491	8.90	275	50	12.5
12000	2.0	80	89.70	430	8.90	300	50	12.0

You will notice that the Q of the Pi-L network does not go up as fast when frequency is lowered as it does with the pi network. Also, the Q remains the same for the pi-L for higher plate loads.

In both **table 3** and **table 4** the

numbers for ten meters are for 29.7 MHz, the highest frequency in the band. This is because you need to know minimum capacitance values to reach this frequency in a five-band transmitter.

effect of swr

A standing-wave ratio of 4:1 will affect the capacitance required at C1 by ±10%, and at C2 by ±25%. If the swr is caused by capacitive reactance, the tuning and loading capacitors are on the smaller side, and if the swr is the result of inductive reactance, the loading and tuning capacitors must be larger. Keep this in mind when selecting component values for a transmitter so you will be able to compensate for an antenna that is not exactly matched to your transmission line.

ssb and CW operation

Table 1 shows that for a given plate supply voltage the plate load impedance is inversely proportional to the input power level. That is, 1000 watts at 2800 volts represents 5000 ohms, while 2 kW at the same supply voltage is 2500 ohms. Pi network values for a Q of 12 for each of these impedances are shown below (capacitance in pF, inductance in μH):

f	R1	C1	L1	C2	Q
4.0 MHz	2500	191	9.18	1097	12.0
4.0 MHz	5000	95	17.38	534	12.0

Note that the required inductance values are quite different.

As an example of what you may expect under actual operating conditions, consider the 2-kW design above (9.18 μH inductor). At 3.5 MHz with 2 kW input, C1 is 252 pF, C2 is 1536 pF and Q is 13.8; not too bad. However, if the input power is reduced to 1000 watts at 3.5 MHz, C1 is 246 pF, C2 is 2287 pF, and Q reaches 27.0, increasing the circulating currents and heat losses in the network.

These figures point out the problems you can run into when you use the same operating voltage and same inductor at different power levels. Fortunately, there are several things which the designer can do to minimize these problems.

variable inductors

There are various variable rotary inductors available on the market which allow the operator to select the proper inductance for 1000 watts CW at the bottom of a band as well as 2000 watts PEP ssb at the top. When compared to fixed inductors, these variable units are fairly expensive, and require a turns counter, further increasing cost. However, they are available in various inductance and current-carrying abilities, so they encompass practically any design requirement.* Also, using a variable inductor eliminates the need for a bandswitch.

bandswitch

The primary purpose of the bandswitch is to change the tap on the tank-circuit inductor to one better suited for the band in use. However, there are several other important functions for the bandswitch:

1. Used to switch input networks to match the 50-ohm output of the exciter.
2. Changes taps on the second inductor in a pi-L network.
3. Sometimes used to switch in additional tuning/loading capacitance on the 80-meter band so smaller variable capacitors may be used in the circuit.

Since you may wish to use a bandswitch in your power amplifier because of these additional uses, the variable inductor may lose some of its appeal.†

tapping the inductor

In a novel approach to this problem a ten-position bandswitch has been used in

*A large selection of variable inductors is available from the E. F. Johnson Company, 1848 10th Avenue, SW, Waseca, Minnesota 56093.

†A good source for excellent high voltage bandswitches and variable capacitors is James Millen *Manufacturing Company*, 150 Exchange Street, Malden, Massachusetts 02148. Millen, unlike some manufacturers, is glad to sell to amateurs in unit quantities.

one design to select different amounts of inductance for the CW and ssb ends of the band.[4] However, the additional switch leads and the large number of inductor taps makes this approach seem impractical for the typical home builder.

Table 5 compares the performance of 1000- and 2000-watt transmitters, as well as a 2000-watt transmitter run at 1000 watts input. In the latter case some additional losses are evident, but they're hardly large enough to cause much excitement. The same comparison shows that the 2-kW transmitter with a Q of 12 at 4 MHz, has a Q of 16.2 at 3.0 MHz. However, considerably more capacitance is required at C1 and C2. The pi-L network will alleviate this problem to some extent as the Q of the pi-L does not increase as rapidly as frequency is lowered as it does with the straight pi network.

Since the 80-meter band is proportionally wider than any other high-frequency amateur band, there is some merit in using an extra bandswitch position for 80 meters.[5] While I have shown previously that this is not required, it would be beneficial because you could select the 75-meter inductor for 4 MHz and 2-kW input, with the 80-meter inductor chosen for 3.7 MHz and 1-kW input.

The primary advantage in such an arrangement would be the ability to add a second input network to match the exciter. Since the input networks have low Q (typically 2 to 3), they are quite broadband and are usually set to a frequency in the middle of the band. However, it would be literally impossible for the same input network to work equally well on both 3.5 and 4.0 MHz, so it would be desirable to have one for each end of the band. From a practical standpoint, this might not be necessary because most operators have ample drive on CW if they are able to push the final to 2-kW PEP on ssb.

table 5. Comparisons between a 1-kW transmitter, a 2-kW transmitter and the 2-kW transmitter operated at 1-kW input. A frequency of 4 MHz was used, but other frequencies from 3 to 30 MHz should produce comparable results. (These calculations are computer derived for comparative purposes and only approximate actual operating conditions.)

	1 kW	2 kW	1 kW on 2-kW transmitter	
Plate voltage	2800	2800	2800	volts
Plate current	357	714	357	mA
Plate load impedance	5000	2500	5000	ohms
Power input	1000	2000	1000	watts
Tube output (typical)	700	1400	700	watts
Power at antenna	672	1343	647	watts
Transmitter efficiency	67.2	67.1	64.7	percent
Network efficiency	96.0	95.9	92.5	percent
Lost in L1 (heat)	27.9	56.9	52.6	watts
Circuit Q	12	12	23.6	
Inductor Q (typical)	350	350	350	
Frequency	4.0	4.0	4.0	MHz
Antenna load	50	50	50	ohms
C1 tuning capacitor	95.5	191.0	187.8	pF
L1 inductor	17.38	9.18	9.18	μH
C2 loading capacitor	533.8	1096.9	1703.0	pF
C1 reactance	416.7	208.3	211.9	ohms
L1 reactance	436.9	230.7	230.7	ohms
C2 reactance	74.5	36.3	23.4	ohms
Current in C1	4.49	8.98	8.83	amps
Current in L1	4.73	9.29	8.93	amps
Current in C2	2.46	7.14	7.70	amps
Voltage across C1	2645.8	2645.8	2645.8	peak volts
Voltage across C2	259.2	366.5	254.4	peak volts
Voltage on antenna	183.3	259.1	179.9	rms volts
Current in antenna	3.67	5.18	3.60	amps

power supply voltage

Since, as I just mentioned, most exciters have more than ample drive for 1000-watts input on CW if they are capable of driving the final to 2000-watts PEP on ssb, it's desirable to include some sort of automatic swamping so the exciter can be run in a normal manner for both ssb and CW. Lowering the plate supply voltage on the final-amplifier tubes decreases the plate load impedance required for a given input power level, therefore requiring more drive to reach this input power level.

For example, if it takes 70 watts drive with 3000 volts on the plate to reach 2000-watts input, then, depending upon the tubes used, it would take 70 to 80 watts drive to reach 1000 watts input with a substantially lower plate supply voltage. At the same time, the voltage-current relationship has changed, lowering the plate load impedance to something much closer to that which would give a Q of 12 with the same inductor.

Also, the plate voltage must be lowered to retain the same Q with the same inductor at the same operating frequency. This voltage reduction can be determined from

$$E2 = 0.71\ (E1) \qquad (11)$$

where E1 is the original plate voltage for 2000 watts input and E2 is the lowered plate voltage for 1000 watts input. For example, a plate supply of 2800 volts for 2000 watts input must be changed to 2000 volts for 1000-watts input at the same operating frequency and circuit Q. Actually, on 3.5 MHz, this would be perhaps 1800 to 1900 volts to provide a Q of 12 at 3.5 MHz (1000 watts input) using a 2-kW transmitter designed for a Q of 12 at 4.0 MHz. However, it is unlikely that you could get 1000-watts input at this plate voltage, even with 100 watts drive on a cathode-driven grounded-grid amplifier.

tuning capacitance

Table 3 and **table 4** show that the C1 tuning capacitance becomes quite small on 10 and 15 meters as the plate load impedance is raised. A typical 2000-watt transmitter might use 2800 volts on the plate, providing a plate load impedance of approximately 2500 ohms. This transmitter would require only 26 pF tuning capacitance to reach the top end of the 10-meter band.

Unfortunately, most modern rf power tubes designed for the 2000-watt level have output capacitances on the order of 10 pF – this leaves about 16 pF for tuning, including stray circuit capacitance.

If you study the various air-variable capacitors available you will find that it is virtually impossible to find a variable capacitor that will provide the necessary spacing for this operating voltage as well as tune the capacitance range needed for both 10 and 80 meters. Also, you must keep in mind that ±10% leeway should be provided to compensate for any swr on the transmission line.

As the plate load impedance increases, the situation becomes even more acute. A 1000-watt transmitter with a plate supply of 2800 volts has a plate load impedance of 5000 ohms – on ten meters this means the tuning capacitor C1 is a total of 13 pF. In this case you would probably have to delete C1 entirely from the circuit and let the capacitance of the power tube supply the necessary tuning capacitance. However, although this has been done, it is not practical.

table 6. Large value at C1 and smaller inductor cause the Q on ten meters to rise very rapidly, especially when running the transmitter at a lower power input which requires 5000 ohms plate load impedance.

f (MHz)	R1	C1 (pF)	L1 (μH)	C2 (pF)	Q
29.7	2500	26	1.24	148	12.0
29.7	2500	32	1.00	210	15.0
29.7	2500	39	0.84	251	18.0
29.7	2500	45	0.72	300	21.0
29.7	2500	51	0.63	348	24.0
29.7	5000	26	1.24	234	24.0
29.7	5000	32	0.98	303	30.0
29.7	5000	45	0.70	437	42.0
29.7	5000	51	0.61	503	48.0

Fortunately, there are several things you can do to help alleviate this situation. You can use a smaller capacitor and add fixed capacitance on 40 and 80 meters, or use two variable capacitors, switching in the larger one on the lower bands. The vacuum capacitor is another possibility because of its low minimum capacitance, often as low as 3 pF. You can also blunder ahead and use a too-large capacitor, allowing the Q to be higher than normal.

Oddly enough, each of these different techniques is currently being used in commercial amateur-band power amplifiers. The vacuum variable provides the best answer to this problem, but it is also the most expensive (by a wide margin). However, the vacuum variable has many advantages worth considering if you are more interested in performance than in total cost.

From **table 6** you can see that the Q on ten meters goes up quite rapidly if too much capacitance is used at C1. One currently available commercial amplifier uses 2800 volts at 2-kW input (plate impedance, 2500 ohms). For ten meters this calls for an input capacitor of about 15 pF after the output capacitance of the tubes has been subtracted. However, this amplifier uses two 20-150 pF capacitors in parallel which are tuned in tandem with a geared arrangement. Thus, their minimum capacitance is about 40 pF, plus 10 pF added by the power tubes, providing a minimum input capacitance of more than 50 pF without any allowance for strays.

Table 6 shows that this gives a minimum Q of 24.0 at the top end of the ten-meter band (around 25.5 at the bottom end). If the amplifier were used at 1000-watts input, the Q would be nearly 48 at the top band edge and over 50 at the bottom!

This amplifier would obviously lose substantial power output in the form of heat in the tank inductor, and proper tuning would be very critical. It would also have to be retuned more often as frequency was changed.

This design is what I call the *blunder-ahead* method. In my mind, it would have been relatively simple for the manufacturer to use only one of the two tuning capacitors on 10, 15 and 20 meters, switching in the second tuning capacitor on 40 and 80.

Another manufacturer does precisely this. He uses a dual-section capacitor — half is used for the three upper bands and the other half is added in parallel on 40 and 80 meters. This provides normal Q for 2000 watts input on 10 meters. It still gives Q in excess of 20 with 1000-watts input, but that's really not too bad. This tuning system gives more than twice the *vernier* of the other system since the maximum capacitance on 20 meters, for example, is 120 pF. On the previous amplifier there is 300 pF available, even on 20 meters. The unit with the lower capacitance is far easier to tune on the upper three bands.

One other circuit trick which can be used quite successfully is to use a dual-section variable, placing the two sections in series rather than parallel. This reduces the minimum capacitance to 10 pF or less.

broadband power amplifier

Many operators need special frequencies outside the five amateur bands for MARS or other purposes, and need a power amplifier which can be tuned up at any frequency in the range from 3.0 to 30 MHz. **Table 7** shows a pi-network design that gives continuous frequency coverage in five switch positions. A pi-L network for similar use is shown in **table 8**. The pi-L is more broadband for a given Q variation, and requires substantially less output capacitance. Both designs are for 2000 watts input with a 2800-volt plate supply, or 1000-watts input at 2000 volts.

component voltage ratings

To determine the peak voltage across C1 you *can* use the maximum dc plate voltage. This is not precisely correct, but it's close enough. Normally you would increase the voltage by at least 30% when selecting a capacitor to prevent arcing if the tank circuit is not perfectly resonated, and to allow for some oxidation if you use an air variable.

There are several ways to determine peak voltage. If the power output is known at this point you can use **eq. 12** to determine peak volatage:

$$E_{pk} = \sqrt{2PZ} \qquad (12)$$

where E_{pk} is the peak rf voltage, P is output power and Z is plate load impedance. For example, in a 1-kW transmitter with 2800 volts on the plate, the peak voltage across C1 and L1 is 2646 volts. (The power output of class-B stages may be estimated at 70% of the input power as this gives some margin of protection and is suitable for this purpose.)

The peak voltage on C2 can also be figured in a similar manner, except that Z in **eq. 12** is the antenna load impedance. Power output may be estimated at 65% of the input. For example, if the output power is 650 watts (for a 1-kW amplifier), and the antenna load is 50 ohms, this represents approximately 254 peak volts across C2. Thus, for a 1000-watt transmitter, a 350-volt, 365-pF broadcast receiver type capacitor could be used successfully. For 2000 watts input at 2800 volts, the peak voltage across C2 would be 367 volts, and the broadcast-tuning capacitor would be too marginal.

In the pi-L network the image impedance must be used when calculating the peak voltage across capacitor C2, and the voltage rating must be substantially higher than for the same capacitor in the pi network. For example, in a 1-kW transmitter, the peak voltage across C2 is about 635 volts: for a 2000-watt amplifier the peak voltage is about 895 volts.

component current ratings

The peak voltage across C1 has already been determined, but to find the current through C1, rms voltage is more useful. This can be found from **eq. 13**:

$$E_{rms} = \sqrt{PZ} \qquad (13)$$

table 7. Pi-network component values for a broadband 3-30 MHz rf power amplifier matching a 50-ohm antenna load. This is accomplished in five bands: 3.0-5.0 MHz, 5.0-8.5 MHz, 8.5-14.4 MHz, 13.5-22.0 MHz and 20.0-30.0 MHz. The Q is set for a minimum of 12 at the top of each band. The 2500-ohm plate load impedance corresponds to a grounded-grid amplifier running 2000 watts at 2800 volts, or a 1000-watt amplifier with 2000 volts on the plate.

R1 OHMS	F MHZ	C1 PF	L1 UH	C2 PF	R2 OHMS	'Q' QUAL.
2500	3.0	433	7.34	2878	50	20.4
2500	3.5	317	7.34	2053	50	17.4
2500	4.0	242	7.34	1517	50	15.2
2500	5.0	153	7.34	878	50	12.0
2500	5.0	265	4.32	1764	50	20.8
2500	7.0	134	4.32	834	50	14.7
2500	7.3	123	4.32	755	50	14.1
2500	8.5	90	4.32	516	50	12.0
2500	8.5	155	2.55	1034	50	20.8
2500	14.0	56	2.55	327	50	12.4
2500	14.35	54	2.55	308	50	12.1
2500	14.4	53	2.55	305	50	12.0
2500	13.5	94	1.67	621	50	19.9
2500	21.0	38	1.67	225	50	12.6
2500	21.45	37	1.67	212	50	12.3
2500	22.0	35	1.67	199	50	12.0
2500	20.0	59	1.22	383	50	18.4
2500	28.0	30	1.22	176	50	13.0
2500	29.7	26	1.22	151	50	12.2
2500	30.0	25	1.22	146	50	12.0

where E_{rms} is the rms voltage, P is the output power *and Z is the plate load* impedance. In the previous example of the 1000-watt transmitter with a 2800-volt plate supply, the rms voltage across C1 is nearly 1870 volts.

To calculate the current through C1 you must first determine the reactance of C1 (**eq. 14**) and calculate its impedance (**eq. 15**). The current is found from **eq. 16**.

$$X_c = \frac{Z_p}{Q} \qquad (14)$$

$$Z_{C1} = \sqrt{R^2 + X_C^2} \qquad (15)$$

$$I = \frac{E_{rms}}{Z_{C1}} \qquad (16)$$

However, since the resistance of a high-quality air-variable capacitor is very small, less than 1 ohm, for all practical purposes the impedance of the capcitor is equal to its reactance. Therefore, the current can be found from

$$I = \frac{E_{rms}}{X_{C1}} \qquad (17)$$

As you can see in **table 5**, the current through C1 is much higher than you might think, with nearly 4.5 amperes flowing through C1 in the 1000-watt transmitter with 2800 volts on the plate. Most air variables and vacuum capacitors can handle this current easily, but you still must be careful when selecting fixed capacitors to pad the variables. Transmitting-type capacitors with high Q and good current-carrying capability are required (such as the Centralab 850 series).

The current through C2 can also be determined with **eq. 17**. However, when calculating the rms voltage across C2 the antenna load impedance must be used in **eq. 13**. *Again, there is substantial current* flowing through C2 — nearly 2.5 amperes in the 1000-watt transmitter.

For all practical purposes, the current through inductor L1 is equal to that through C1. It is actually a little higher, and the following formula is reasonably correct for class B:

$$I_{cc} = 1.05\, Q_o I_p \qquad (18)$$

where I_{cc} is the circulating current, Q_o is loaded circuit Q and I_p is the indicated plate current. **Eq. 18** is a close approximation that compares favorably with answers derived from using complex vector analysis of reactive components used in rf circuits at resonance.

inductor power loss

To determine heat losses in the inductor, it is necessary to know the rf resistance of the inductor. Then you can use **eq. 19** to find power loss.

$$P = I^2 r \qquad (19)$$

where I is the circulating current and r is the rf resistance.

To minimize these losses, the inductor should be silver plated, as should all leads to the bandswitch. Power losses on the order of 30 to 100 watts are not unusual, even with low standing-wave ratios. The use of tubing is encouraged, particularly on the higher frequencies to provide better unloaded Q.

table 8. Pi-L network component values for a broadband 3-30 MHz rf power amplifier matching a 50-ohm antenna load. This is accomplished in five bands: 3.0-5.0 MHz, 5.0-8.5 MHz, 8.5-14.4 MHz, 13.5-22.0 MHz and 20.0-30.0 MHz. The Q is set for a minimum of 12 at the top of each band. The 2500-ohm plate load impedance corresponds to a grounded-grid amplifier running 2000 watts at 2800 volts, or a 1000-watt amplifier with 2000 volts on the plate.

R1 OHMS	F MHZ	C1 PF.	L1 UH.	C2 PF.	L2 UH.	R3 OHMS	R2 OHMS	'Q' QUAL.
2500	3.0	388	9.00	1510	3.90	158	50	18.3
2500	3.5	292	9.00	1015	3.90	197	50	16.0
2500	4.0	228	9.00	717	3.90	242	50	14.4
2500	5.0	153	9.00	400	3.90	350	50	12.0
2500	5.0	237	5.29	935	2.29	154	50	18.6
2500	7.0	127	5.29	391	2.29	253	50	14.0
2500	7.3	118	5.29	351	2.29	270	50	13.5
2500	8.5	90	5.29	235	2.29	350	50	12.0
2500	8.5	139	3.12	549	1.35	154	50	18.6
2500	14.0	56	3.12	150	1.35	330	50	12.3
2500	14.35	54	3.12	141	1.35	345	50	12.1
2500	14.4	52	3.12	139	1.35	350	50	12.0
2500	13.5	85	2.04	323	.89	165	50	18.0
2500	21.0	38	2.04	103	.89	325	50	12.5
2500	21.45	36	2.04	97	.89	335	50	12.3
2500	22.0	35	2.04	91	.89	350	40	12.0
2500	20.0	53	1.50	192	.65	183	50	16.7
2500	28.0	29	1.50	80	.65	315	50	12.7
2500	29.7	26	1.50	68	.65	345	50	12.1
2500	30.0	25	1.50	67	.65	350	50	12.0

A suitable inductor for the L section of the pi-L network consists of two inches of Air-Dux 1606T (6 turns-per-inch, no. 14, 2" diameter). It should be placed at right angles to the main pi inductor to avoid mutual inductance.

frequency	number turns	approximate inductance
3.0-5.0 MHz	10.00	3.90 μH
5.0-8.5 MHz	6.75	2.25 μH
8.5-14.4 MHz	4.75	1.33 μH
13.5-22.0 MHz	3.50	0.83 μH
20.0-30.0 MHz	3.00	0.65 μH

It may come as a surprise to find that the conductivity of silver is only slightly superior to that of copper. In fact, a silver-plated coil is little more efficient than a *new* tank coil made of copper. Copper, however, oxidizes, and the outer rf-current-carrying layer becomes less effective. On the other hand, silver develops a form of silver sulfide on its outer surface which barely affects its conductivity. Over a period of years the silver-plated coil will retain most of its original conductivity.

safety

An rf choke should be used at the antenna output of any pi or pi-L network. This choke should be large enough to blow the overload relay (or fuse) in the high-voltage power supply if the dc blocking capacitor should short out. This is the only backup protection you have to keep high dc voltage off the pi-network components if the blocking capacitor shorts out. This rf choke also keeps any dc component off the antenna.

RTTY and ssb

Many amateurs are interested in RTTY as well as CW and ssb. Since RTTY is essentially 100% key down, it's quite hard on the various components in the transmitter. On ssb, the typical duty factor is 30% to 50%, depending on how much ALC and other compression you use. Typically, however, the *average* circulating current in the network is perhaps one-third of that for key-down operation.

Table 5 shows that 2000-watts key-down gives comparable circulating currents to that of the same transmitter run at 1000-watts key-down with the same plate voltage and same inductor. This is due to the higher Q that is being used. Because of the lower duty cycle of ssb, running a 2000-watt transmitter key-down at 1000 watts for RTTY is three times as hard on the transmitter as running 2000-watts PEP! This is rather startling, and indicates why some rf power amplifiers should not be used on RTTY, although they are perfectly suitable for ssb at higher input power levels.

Conversely, it follows that if a manufacturer guarantees his unit to run indefinitely at 1000-watts key-down RTTY, that same transmitter should last forever at 2000-watts PEP ssb. Some manufacturers hedge if this specific question is posed to them.

summary

Using a 2000-watt rf power amplifier at the 1000-watt level for RTTY or CW poses certain inherent problems regarding heat and efficiency. High plate supply voltages raise the plate load impedance to the point where it may be difficult to get the minimum capacitance required for resonance on 10 and 15 meters.

When building a high-power final amplifier, consideration must be given to selecting components which will handle the voltage and currents encountered in the circuit. The formulas given in this article should make it relatively easy for the builder to predict what these voltages and circulating currents will be before he actually builds the amplifier.

Computer-derived tables provide much data for the builder, and clarify many design points only hinted at in previous articles. I hope that the information presented here will be of benefit to anyone who builds or buys a final rf power amplifier.

acknowledgements

Many people are interested in pi and pi-L networks, and have been of direct assistance. Providing particular assistance was Bob Sutherland, W6UOV, of EIMAC. I also spent a great deal of time reading articles written by George Grammer, W1DF, former technical editor of *QST*. His work in this field, and his series of three articles in *QST*[5] represent an outstanding contribution. Bill Craig, WB4FPK, was most helpful, as was Garey Barrell, K4OAH. Bill Carver, K6OLG, also provided stimulating comments.

The Computer Terminal Corporation of San Antonio, Texas, provided over 100 hours of computer terminal time which was invaluable in this project.

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ham radio

More Details? CHECK—OFF Page 110

quick and easy
speaker driver module

A compact, high-output, low distortion audio module provides an easy short-cut in the design of solid-state receivers and mobile equipment

Jerry Vogt, WA2GCF, 182 Belmont Road, Rochester, New York 14612

First introduced by Bendix a few years ago, the BHA-0001, BHA-0002 and BHA-0004 hybrid solid-state audio amplifier modules provide two watts, fifteen watts and five watts of audio output, respectively, to drive a 3.2-ohm speaker from a low-level, high impedance audio source. The 1972 Allied Radio Industrial Catalog lists these as "amazing space-age microcircuit modules each containing a complete audio amplifier, employing the latest thick-film construction and requiring fewer external components than monolithic partial amplifiers. Its simplicity permits easy assembly in less than one hour, even for those with semi-technical skills, thus saving endless hours of needless drudgery." For those who have played with the typical complementary symmetry amplifier, as I have, you will be surprised to find out that you can place one of these devices down on a board with a few external capacitors and have your amplifier working within minutes without worrying about getting the bias and feedback figured out for that long string of dc-coupled transistors.

I decided to try the BHA-0004, which provides a good amount of audio output (five watts) for a mobile rig. The rather high price, ($18.80 in single lots) was discouraging when I first looked at the catalog, but you only live once. Built as a module separate from the rest of the receiver, you can use it over and over on new projects.

I started thinking about possible uses for the unit. The list seemed almost endless. The circuit can be terminated at the input with a 3-ohm resistor and used as an audio booster for mobile gear with flea-power output stages. It can be used to drive one car speaker with many different radios. Each radio is fed to the module input through low-resistance pads in place of the existing radio's speaker. You can use it to drive an electronic siren or a speaker mounted under the hood of the car, or as the basis for an intercom system. Two of them make a stereo amplifier for an fm tuner. I have built quite a few fm receivers, using the

the circuit

The equivalent circuit for the device is shown in **fig. 1**. It is very similar to a circuit once promoted by Motorola for use with discrete transistors, using the 2N4918 and 2N4921 complementary output transistors. Basically, the internal circuit of the BHA-0004 consists of dc-coupled transistors. Output transistors, Q4 and Q6, operate as class-B symmetrical amplifiers, driven by Q3 and Q5. C1 suppresses high-frequency oscillations. R9 and R10 limit the output current that can be drawn through Q4 and Q6 from the external load. CR1 and CR2, in conjunction with R8, provide the voltage drop required between the bases of Q3 and Q5 to prevent cross-over distortion.

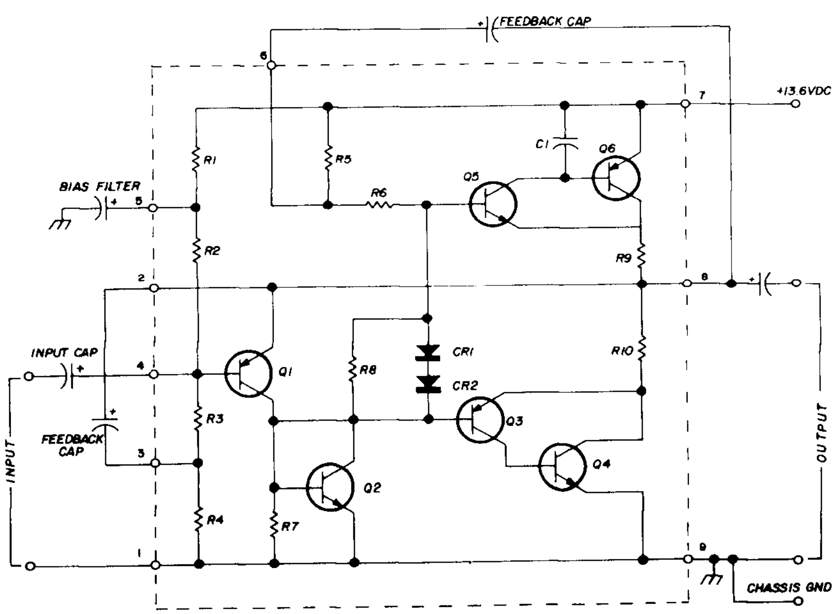

fig. 1. Equivalent internal circuit of the BHA-0004 audio amplifier, with external components added for understanding.

Sprague ULN-2111A IC limiter/detector and I am now starting to use this audio amplifier as a standard external module for my new receivers. The level from one of the fm detector ICs is perfect for driving these speaker amplifiers.

If the bases of Q3 and Q5 were tied directly together, the emitter-base forward turn-on voltage of the two transistors would provide about 0.7 volt of reverse bias to the transistors, causing distortion, especially at low signal levels.

R5 and R6 provide a dc voltage to the biasing circuit for Q5 and Q3.

The easiest way to visualize the coupling from Q2 to the Q3 and Q5 pair is to see Q2 as a variable resistance in the bottom leg of a voltage divider consisting of R5-R6-CR1-CR2-Q2. In this way, Q2 modulates the bias applied to both Q3

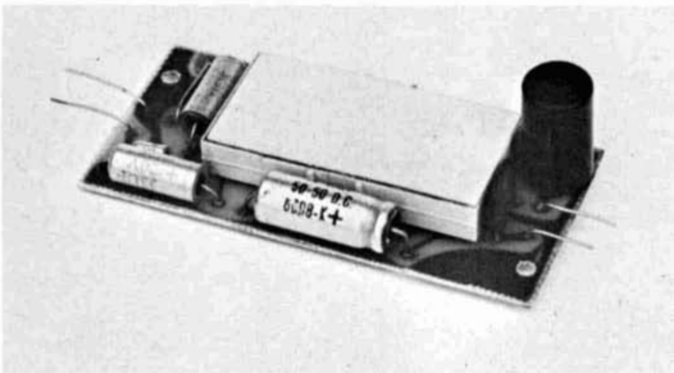

Photo of the completed audio module on the printed-circuit board.

and Q5 and drives them. It is at this point, where Q2 drives complementary transistors Q3 and Q5 (opposite polarities), that the single-ended signal is split to push-pull for the output stage. R8 provides compensation over the turn-on

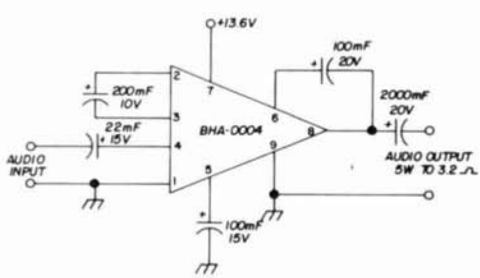

fig. 2. Test circuit recommended by the manufacturer.

curve of CR1 and CR2. C2 suppresses parasitic oscillations. R7 acts as a load for Q1, the input transistor, which is directly coupled to the base of Q2. R1 through R4 provide dc biasing for the entire string of transistors by establishing the current flow through Q1 at idle. A tap in the circuit between R1 and R2 allows an external capacitor to be connected to filter or decouple the bias circuit.

A tap between R3 and R4 and one between R5 and R6 allow external capacitors to be connected from the output back to the input of various stages. This feedback minimizes distortion and levels the frequency response. The input is ac coupled to the base of Q1, and the output is capacitively coupled to the load, usually a loudspeaker. The circuit is optimized for operation from the normal car battery voltage of 13.6 Vdc. Preset idle current and center voltage provides ideal operation over a wide range of load conditions. Notice the benefit of this circuit in not requiring an output transformer.

external circuitry

The external connections recommended by the manufacturer are shown in **fig. 2.** The values given were selected for hi-fi operation, though, and are undesirable for amateur use in communications circuits. If you want to operate the module for music reproduction, however, that is the route to take. The components shown also allow you to obtain full power output, but that was not a requirement in the design which follows. Specifications for the unit in this "hi-fi" setup are 5 watts output over the range 25 Hz to 15 kHz with an input of 20-mV rms. Distortion should be 1% or less.

Although the manufacturer states that

no heat sink is required for full-power operation at room temperature, I think it would be a good idea to cement a few aluminum fins to the ceramic top of the module for protection. Remember that a replacement is expensive if you exceed the limits a little bit. The fine print with the device tells you to consider heat-sink-

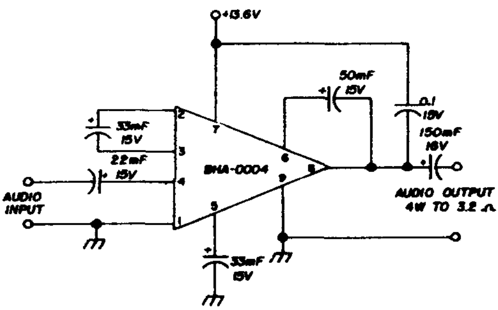

fig. 3. The modified circuit for compact packaging and communications work.

ing for operation over two watts at elevated temperatures. The thing to remember is that the unit itself generates some heat, and that heat will raise the ambient temperature if the device is operated in a package which allows no air circulation — a common method of packaging solid-state mobile gear.

construction

The circuit as modified for use is shown in fig. 3. There are three reasons for the modifications: to reduce the size of the assembled circuit board, to restrict the frequency response to the communications range and to save the cost of unnecessary expensive parts. Basically, the values of all of the capacitors were reduced. An added component, a 0.1-mF capacitor from the B+ line to the output line prevents high-frequency oscillations found in one of the breadboard models.

*In conjunction with this article, a limited supply of completely assembled and tested assemblies are being made available for $19.50 postpaid. Contact Hamtronics Inc., 182 Belmont Road, Rochester, New York 14612. Please include remittance with order and allow two to three weeks for delivery.

With the circuit shown, the sensitivity is not quite as great as with the manufacturer's recommended circuit; however, it was felt to be adequate, especially in light of the high output normally available from the fm detectors in current use in IC receivers. The modified circuit provides four watts output over the 350- to 3500-Hz range with an input of 750-mV rms. No heat sink is required with this installation. The size of the circuit board, when assembled with the components in fig. 3, is approximately 2 1/8 x 3 1/4 x 1-inch high. This size works out nicely for mounting in many of the cases available to the home builder.

There are really no secrets or tricks used in construction of the assembled circuit board.* Fig. 4 shows the basic layout I used. The board layout was based on readily available parts, and spacing was set up to allow substitution if necessary. I replaced the resistor from pin 2 of the module to the 33-mF capacitor with a plain jumper. I found the resistor unnecessary. The only part at all out of the ordinary is the 150-mF capacitor,

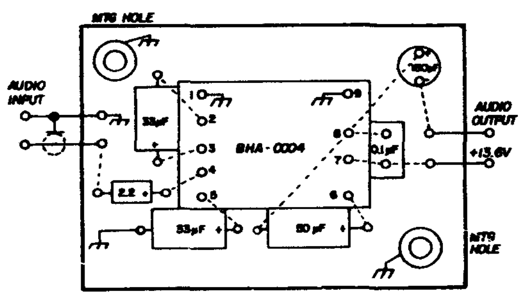

fig. 4. Suggested layout for a printed-circuit board (not to exact scale). The layout is very flexible and can be modified to suit the parts on hand.

which is a vertically mounted type which happened to be available. A more standard tantalum type (for small size) can be mounted in its place, without increasing the size of the board, by mounting it vertically with one lead folded over the side of the capacitor.

ham radio

three-band high-frequency log-periodic antennas

These three-band wire-beam log periodics for 20, 15 and 10 meters are inexpensive, easy to build and provide excellent performance

G.E. Smith, W4AEO, 1816 Brevard Place, Camden, South Carolina 29020

Log-periodic antennas offer a number of operating advantages to the amateur who wants consistent contacts over long distances. Although there are several commercial rotatable high-frequency log periodics available on the market, they are large and complex, and home construction of a rotatable L-P is impractical for the average amateur. However, the same performance can be obtained from a light-weight wire log periodic which is fixed in one direction.

The log periodics described in this article are wire beams, so they are low cost and easy to build. The log-periodic antenna shown in **fig. 1** covers the frequency range from 14 to 30 MHz and can be used on the 10-, 15- and 20-meter bands. It can be erected in a 40- by 50-foot space and provides a minimum of 8-dB forward gain, a front-to-back ratio of 15 dB or more, and has low swr that is constant over each of the three amateur bands.

Although log periodics can be designed to cover a 10:1 frequency range, they are quite large. For this reason the antennas discussed in this article are limited to fixed, non-rotatable types for 20, 15 and 10 meters.

Since all details of log-periodic theory and design have been covered in previous articles, this data will not be repeated here.[1,2,3] I have put up a number of fixed log periodics in various directions, and for different frequency ranges, including L-Ps for 20, 15 and 10; 20 and 15; 15 and 10, and a big brute for 40, 20 and 15. All the L-Ps installed so far have provided excellent on-the-air performance.

At my station these antennas are suspended from tall pine and cedar trees, with the elements 45 to 50 feet above ground. All were originally beamed south so I could evaluate their performance rapidly with the rather consistent band openings I have to South and Central America.

The log-periodic antenna illustrated in **fig. 1** has an apex angle of approximately 36° (a=18°). If you want higher forward gain, and if space is available, the design in **fig. 2** has a minimum gain of 10 dB for each of the three bands. However, its overall length is 100 feet. This antenna has been in use at my station for the past year, and has done an excellent job.

When operating on 20 meters, using an ordinary dipole (at the same height as the log periodics), reports from South and Central America average S8 to S9. When I switch to the log periodic the signal reports usually improve to 20 dB over S9. In most cases the S-meter in my receiver confirms this.

Although these reports seem to indicate gain greater than 10 dB, when compared to the dipole I use as a standard, some of the apparent gain is probably due to the lower radiation angle of the log periodic. Also, the theoretical gain of a log periodic is the result of line-of-sight tests on vhf and uhf antenna ranges, so they are not directly translatable to high-frequency performance.

If you check the specification sheets for commercial log-periodic antennas, you will find that the manufacturers rate their 12- and 13-element log periodics at 10 to 13.5 dB *over average soil conditions.* Front-to-back ratios are rated from 14 to 16 dB.

The lower radiation angle of the log periodic always results in higher performance than that predicted by theory, particularly on 20 meters. And, the longer the DX path, the greater the difference when compared with a dipole.

Operational tests on 15 and 10 meters have not been as outstanding as those on 20 meters, but most reports give at least a 10 dB advantage to the log periodic.

Reports off the back of the beam generally show a front-to-back ratio of at least 15 dB (also confirmed by my receiver S-meter). The front-to-back ratio is generally best on 20 meters, and slightly less on 15. The conditions on 10 meters have been too erratic to make good front-to-back signal-level comparisons.

One of the big operating advantages of the log periodic is the apparent diversity effect on receive. This is particularly noticeable during conditions of severe fading. Even signals coming in from the back of the antenna often have less fading when compared to a dipole. Evidently the large size (large capture area) of the log periodic provides this effect.

Since the log periodic is a broadband antenna it is well suited for operating on any frequency within the amateur bands it is designed for. The swr is low and nearly constant over the entire length of each band. Also, because of its broadband characteristics, there are no critical element or impedance-matching adjustments necessary after you put it up.

theory

According to log-periodic theory, the longest rear element must be at least 5% longer than one-half wavelength at the lowest desired operating frequency. For example, if the lowest operating frequency is 14.0 MHz ($\frac{1}{2}\lambda$=33.4 feet), the rear element must be not less than 35 feet long (33.4 feet + 5%). This element would resonate at about 13.3 MHz.

The shortest front element should be 45% to 50% shorter than one-half wavelength at the highest operating frequency. With 29.7 MHz as the upper frequency limit of the antenna, the front element should be resonant at 44.55 MHz mini- would only require a space about 25 feet wide by 35 feet long. You could even build a rotary log periodic for 15 and 10 meters on a 25-foot boom.

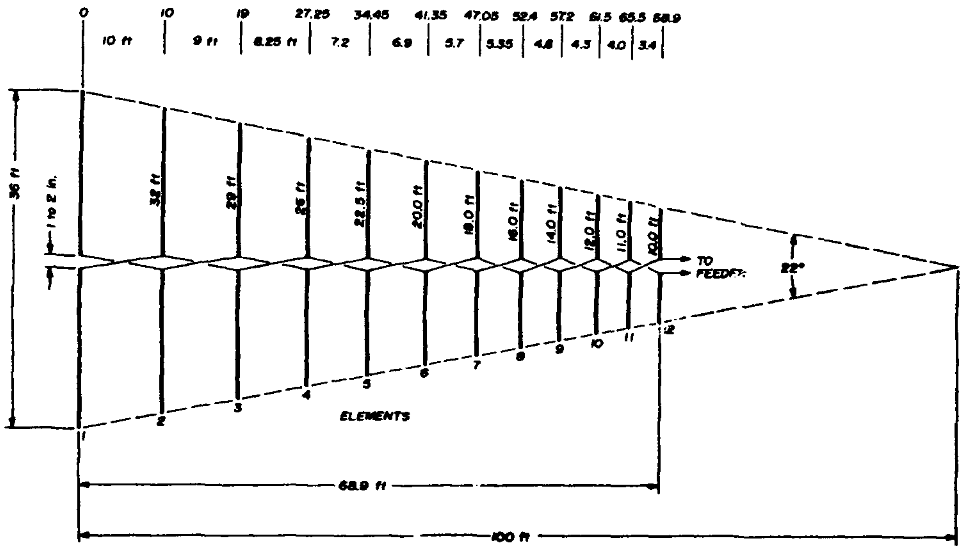

fig. 1. Three-band log-periodic antenna for 20, 15 and 10 meters provides approximately 10 dB forward gain.

mum (29.7 MHz + 50%).

For these reasons, a log periodic designed for 20, 15 and 10 meters should have a low-frequency cutoff of 12 to 13 MHz; high-frequency cutoff should be at least 45 MHz.

The log-periodic antennas shown in figs. 1 and 2, since they have the same number of elements, cost about the same, $35.00. However, this does not include support masts or feedline. This is not too bad for an antenna which provides 10 dB gain and performs equally well over each of the three amateur bands, 20 15 and 10.

If you don't have the space for one of these large antennas, you can reduce the size by eliminating one of the bands. For example, if 20-meter operation is not required, the three rearmost elements can be deleted. This leaves a 9-element log periodic that performs admirably on 15 and 10. The smaller, two-band antenna

If 10-meter operation is not required, you can remove the three front elements, leaving 9 active elements for operation on 20 and 15. This reduces the length of the antenna by about 6½ feet.

construction

Since I use tall trees around my house to support the log periodics, weight must be kept to a minimum to gain maximum height. For the antenna elements, I use no. 15 aluminum electric fence wire which is available from Sears (catalog no. 13K22065). This wire is very inexpensive at $8.70 for ¼ mile of wire and is extremely light weight and easy to work. It has good strength and should also be suitable for rhombics and other long-wire antennas.

Connections to the aluminum wire are made by winding no. 16 or no. 18 tinned copper wire around the aluminum wire for about one inch. The junction is then covered with plastic electricians tape to keep out the rain and minimize electrolysis between the two dissimilar metals.

All the center insulators used in my

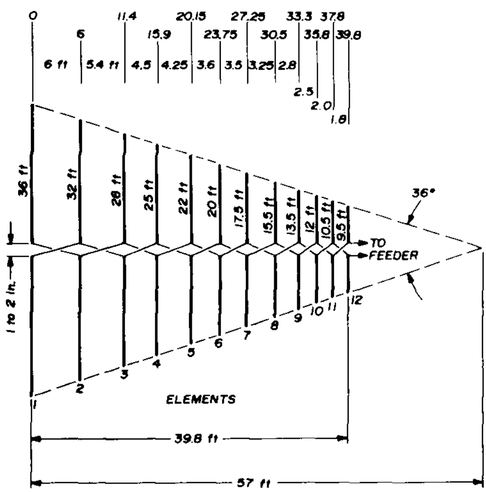

fig. 2. This three-band log periodic provides nearly the same performance as the design shown in fig. 1, but requires slightly less space.

log periodic were made from Lucite or Plexiglass sheet, 1/8- to 1/4-inch thick. After cutting and drilling, the center insulators cost about 20 cents each. These insulators are also used as spacers and stringers for the open-wire feeder which runs down the center of the log periodic. For the three-band log-periodics shown in **fig. 1** and **2** you will need 12 center insulators.

The end insulators are made from monofilament fishing line (40 to 50 lb. test). At the rear element, however, if you use two rear masts, Isolantite antenna insulators should be used at the ends of the elements because the strain at this point is quite high, and may exceed the rating of the monofilament.

The monofilament apparently provides more than adequate insulation for 1000-watt transmitters. YV5DLT has advised that he has experienced no breakdown problems when using his SB-220 linear at full output. The monofilament I used is Sears Catalog number 6KV32232 (40 lb. test), which is priced at $1.88 for a 325-yard spool.

installation

The log periodic is suspended from the center with 3/16-inch nylon line (A in **fig. 4**) and two side catenary lines (C in **fig. 4**). The 3/16-inch, 800 pound test nylon line used for the A line carries most of the load and strain of the antenna, including the open-wire feeder and the center insulators.

Before installing the antenna, string the center nylon line through the ¼-inch hole at the top of each of the 12 center insulators. After the insulators are on the line, stretch the line between two posts about 60 or 110 feet apart (depending which log periodic you are building). The line should be at shoulder height so it's easy to work on.

The first center insulator will support the longest element as well as the rear end of the center feeder. A knot is tied in the A line just in front of the insulator to keep it from slipping forward on the line. Make sure the other 11 insulators are on the other side of the knot.

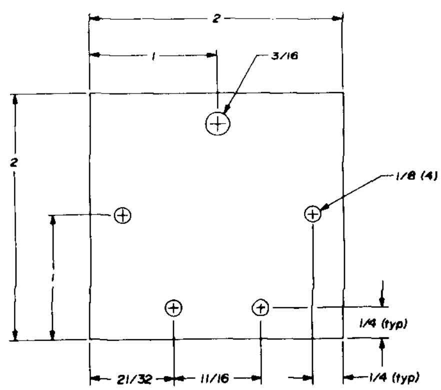

fig. 3. Insulators used in the construction of the log-periodic wire beams. Material is ¼" Lucite or Plexiglass.

Wrap several layers of masking tape around the nylon line to the rear of the first insulator. Leave a little space between the tape and the insulator so it hangs freely from the nylon line.

Now, using a steel tape, measure the spacing to the second insulator. Secure this insulator in place with several layers of tape around the line on each side of the insulator. Be sure to leave enough space between the tape layers so the tape or plastic tape, which often loosens up. The masking tape hardens and keeps the insulators in their correct position.

After the center insulators have been installed, assemble the parallel open-wire feeder by threading the two stranded

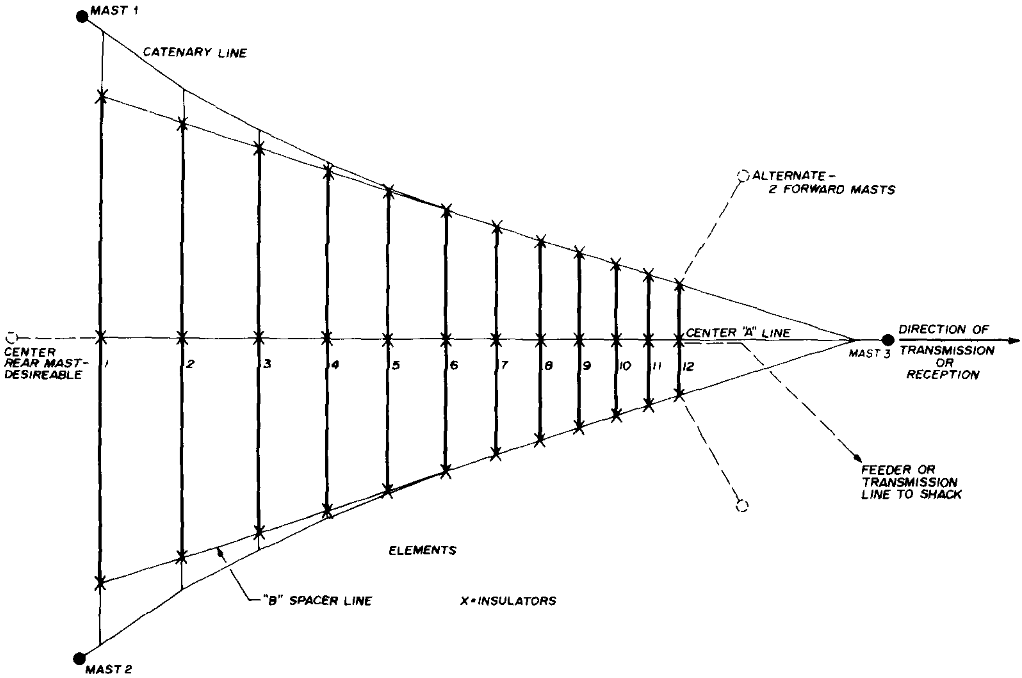

fig. 4. The log-period wire beams are supported by three nylon lines: the center A line and the two C catenary side lines.

insulator hangs freely on the center support line.

Continue along the center support line, measuring element spacing and installing center insulators, until all 12 insulators are correctly spaced and secured to the line. When spacing the insulators along the line it's a good idea to check the total spacing to make sure that no additive errors occur as spacing progresses. The total distance from the first insulator to the last should be 39.8 feet for the log periodic in **fig. 2**. For the larger antenna in **fig. 1** this distance is 68.9 feet.

I have found that masking tape will stand the weather better than friction

wires (7/24 or equivalent) through the two number-2 holes in the center insulators. The parallel feeder wires are secured to the insulators with a few turns of no. 18 wire as shown in **fig. 5**.

The spacing of the center feeder does not appear to be critical. I have used spacings from 3/4 to 2 inches on different log periodics. Some of the commercial vhf-tv log periodics have center spacing up to 5 inches. No doubt this spacing could be used on high-frequency log periodic antennas, but the larger spacing would require more Lucite for the center insulators, and this would increase both cost and weight.

When the center feeder is in place, cut

the 12 elements from a length of aluminum electric-fence wire using the dimensions shown in the illustrations. Make the elements slightly longer, so there is several inches of wire for attaching the monofilament end inculators, and at least 8

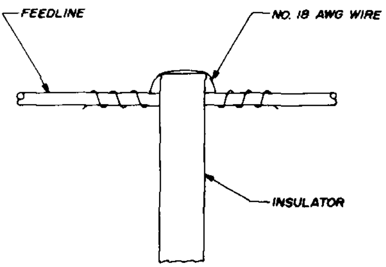

fig. 5. Lucite insulators are secured to the center feedline with a few twists of no. 18 wire.

inches for attaching the center insulators and connecting to the center feeder. Every other element is transposed as shown in **figs. 1** and **2.**

Attach the 12 elements to the center insulators, starting at one end of the antenna and working toward the other. Leave the ends at the center disconnected for the time being. After all the elements are attached to the center insulators, install the monofilament end insulators.

The two B lines are simply longitudinal spacers to keep the elements parallel during assembly and at right angles to the center feeder. These lines can be 1/8-inch or smaller since they carry no load (number 18 nylon twine, 165 lb. test, is satisfactory, and inexpensive at $1.85 for a 500-foot spool).

Next, the elements are attached to the two C bridles or catenary lines which take most of the side load. For the C lines, 1/8-inch nylon (375 to 500 lb. test) is suggested. This can be purchased at marine or hardware stores for about 3 cents per foot.

The center A line and the two C catenaries should be stretched tight, about 6 feet off the ground. When the catenaries are stretched into place they will appear as a large V, with the apex aimed in the desired operating direction. The A line should pass through the center of the V, bisecting it equilaterally.

By suspending the complete antenna between the same supports that will be used in the final installation, but at six feet above the ground, it is easy to adjust the tension of the elements from the ground.

The distance from the shortest element to the apex of the V should be 17.2 feet (**fig. 1**) or 31.1 feet (**fig. 2**). Less than this will allow the front element to sag too much.

Attach each of the elements to the catenaries with nylon twine, working from the shortest element to the longest. Use temporary knots, because it may be necessary to adjust the tension after all the elements are installed. Note that the six front elements usually fill the space between the B and C lines where the B line is adjacent to the C line.

Starting at element number 7, the C lines will require more and more separation to provide sufficient tension on the longer rear elements.

At this point it may be necessary to adjust the spacing between the end insulators and the C lines so there is as little element sag as possible, but don't put too much strain on the nylon support lines. There will also be some fore and aft sag of the center A line due to the weight of the feeder, insulators and wire elements, but the antenna should now be starting to take shape.

center feed

The center feedline to each of the elements of the log periodic must be transposed as shown in **figs. 1** and **2.** I have tried two methods of doing this. On the antennas shown here each feeder is transposed 180° between each of the elements. This is the system usually used in the schematic representations of the log periodic.

With this method of feeding power to the elements, insulated wire must be used for the feeder. With high power, you might have problems with insulation breakdown. Bare wire can be used for the feeders, but insulated transposition blocks are required between elements, adding both weight and cost.

The second center feed method uses *an open wire parallel* feeder with criss-crossing wires to each of the elements as shown in **fig. 6.** This feed system is easier to build, and presents a neater appearance.

feedline

Most of the rotatable vhf and uhf log-periodic antennas proviously described in the amateur radio magazines have used 50- or 72-ohm coaxial feedlines.[4,5,6] However, a coaxial feedline is not suitable for the high-frequency log periodics described here because the cable is much too heavy. For these antennas, a light-weight feeder is required.

Normally, the log periodic is fed from the front (short-element) end. The input impedance at this point is about 30 to 35 ohms, as measured with an Omega Antenna Noise Bridge.* I checked several different log-periodics with the Noise Bridge, and all fell into the 30- to 35-ohm range.

However, if the open center feed is extended to the apex, the input impedance increases to approximately 100 to 300 ohms.[8] The open center feed operates as an impedance transformer, and at a point that is an odd number of wavelengths from the active elements on 20, 15 and 10 (20 meters, element 2; 15 meters, element 5; 10 meters, element 8) the input impedance remains fairly constant over each of the amateur bands. This point is within several feet of the apex.

Since the input impedance of the antenna depends upon feed point location, several possible transmission lines may be used. Since the input impedance at the front element is quite low, one of the best methods of feeding the antenna is with tuned open-wire feeders, with an antenna tuning unit between the coaxial output of the transmitter and the open-wire feed-line.

Although a coaxial feedline adds a great deal of weight to the antenna, and results in a sagging log periodic, it can be connected directly, through a balun, to the front-element feed point. Tests here, with RG-8/U coaxial cable, indicate a fairly good match on 20, 15 and 10. The standing-wave ratio on the 14-MHz band ranges from 1.1:1 to 1.3:1 from one end of the band to the other. On 21-MHz, the swr varies from 1.3:1 to 1.7:1, and on 28 MHz, the swr is from 2.0:1 up to 2.5:1.

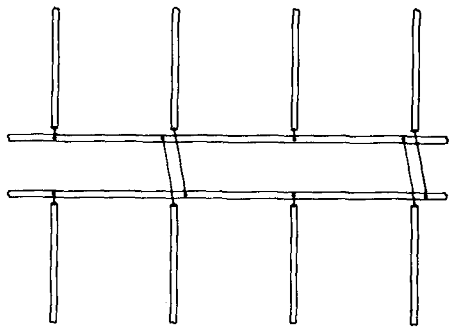

fig. 6. The required feedline transposition is most easily accomplished with criss-crossing wires to each of the antenna elements.

The swr on 10 meters is somewhat higher than that on the two lower bands, but it is still within tolerable limits, and on-the-air tests on 10 meters indicate very good performance.

At my station neither the tuned open-wire feeder nor the coaxial cable were suitable for a permanent installation. Since I use trees to support the antenna, the weight of the coax cable caused the antenna to sag too much, and valuable height was lost. Also, several of these antennas are several hundred feet from the station, so the cost of coaxial feedline is prohibitive.

The long length of the feedline makes open-wire feeder impractical because of the large number of spacers to be in-

*When using the Antenna Noise Bridge, the *frequency* dip normally exhibited by a sharply tuned antenna is completely absent with a log periodic because of its broad-band operation.

stalled, and the amount of work required to install the transmission line.

For these reasons I tried 72- and 300-ohm tv twin-lead. I tried the 72-ohm twin-lead first, connecting it to the transmitter through a short section of coaxial cable. For minimum swr (at the transmitter) I had to prune the length of the 72-ohm feeder – by removing short lengths (about 1/8-wave at 28 MHz), and making swr measurements, I arrived at a feeder length which provided fairly low swr on each of the three bands. A 1:1 balun between the twin-lead and the coax input didn't appear to make any difference.

When I tried out the 300-ohm twin-lead, connected near the apex, I used a 4:1 balun transformer between the twin-lead and the coax to my transmitter. This system worked quite well, and provided good performance on all bands. Although tv-type twin-lead will not handle a kilowatt, it is adequate for the 250 watts which I use. For higher power installations, transmitting-type 300-ohm twin-lead is available.

With the 300-ohm twin-lead feedline, the swr on 14.0 MHz was measured at 1.7:1, dropping to 1.5:1 at 14.2 MHz and 1.3:1 at 14.35 MHz. On 21.0 MHz the swr was 2.2:1, increasing to 2.5:1 at both 21.2 and 21.45 MHz. On ten meters, the swr was 2.2:1 at 28.0 MHz, dropping to 1.9:1 at 28.5 MHz, increasing to 2.1:1 at 29.0 MHz, and dropping again to 1.9:1 at 29.5 MHz. When plotted on a graph, these swr figures result in pretty flat performance over each of the three amateur bands.

summary

Since the forward lobe of the log periodic is generally broader than that of a Yagi, it is quite suitable as a fixed, non-rotatable, gain antenna. When my antenna farm is completed, I will be able to cover the United States and several continents with six three-band log-periodic antennas. Six dpdt relays will be used to connect the desired 300-ohm feeder to a 4:1 balun which is connected to the coaxial transmission line to the transmitter.

These light-weight log periodics have been very durable. One has been up for a year, with absolutely no trouble. Three were up last winter and withstood two bad ice storms; they sagged a bit with the ice load, but as soon as the ice melted, they returned to their normal height. They have also withstood a couple of twisters which passed a block away, snapping a number of tall pines.

If you like to build and test antennas, or are looking for DX and consistent contacts in a certain direction, I highly recommend the light-weight log periodics described here. At the present time I am working on two side-by-side log periodics pointing in the same direction. This should increase the gain by about 3 dB, to 13 dB for the two-antenna system.

I want to thank all those who have been helpful in giving reports and running tests on the log periodics, especially the Central and South American operators, for their patience and accurate reports. Special thanks goes to YV5DLT in Caracas for the many tests over the past year, and the nearly daily schedules during the design and testing of these antennas.

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ham radio

RTTY distortion:

causes and cures

Anomalies peculiar to transmitted and received RTTY pulses are analyzed, with suggested improvements to reduce printout errors

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Many amateurs who pursue RTTY go to great lengths with fsk demodulators, keyers, and related equipment to get near-perfect printouts. Nearly every innovation is discussed, tried, and eventually designed into RTTY stations. Pulse distortion, however, seems to be rarely appreciated and often turns out to be the culprit causing many unnecessary printout errors.

When transmitting, it is the responsiblity of the RTTY amateur to send a clean signal with near-zero distortion. Frequency-shift circuits must be designed with regard to this requirement; and key-boards, TDs, and other transmitting devices require careful adjustment.

Distortion must also be considered in receiving circuits to minimize errors. This requirement applies not only to the demodulator but also to the dc loop circuit and the adjustment of the teleprinter and reperforator. This article defines common distortion terminology and discusses some of its causes, remedies, and measurement techniques.

definitions

Pulse distortion occurs in two ways – by *bias* and *end distortion.* Each can have two polarities: mark and space. As shown in **fig. 1**, when a transmitted or received RTTY signal is compared with a perfect signal carrying the same information and referenced to the space-going edge of the start pulse, the following is evident:

a. *Bias* affects the mark-going pulse edges.

b. *End distortion* affects the space-going pulse edges.

Each type of pulse distortion is measured in percent and defined over the range 0-100 (**fig. 2**). Note that the signal completely disappears as bias distortion approaches 100 percent.

Distortion, D, can be expressed as

$$D = 100B(\Delta T)$$

where B is the baud rate in units per second and ΔT is the time error in seconds of the edge in question as measured from the correct edge location.

sources of distortion

Any circuit condition that imparts a delay to RTTY pulses acting on one polarity more than another will generate bias distortion. End distortion, in pure form, is rare since its effect on a signal selectively leaves the start pulse intact and is thus usually accompanied by equal or greater parts of bias distortion. Here are some common examples.

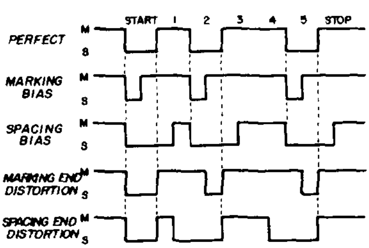

fig. 1. Basic distortion types on the letter F.

Inadequate open-loop voltage. When a teleprinter loop includes a large series inductance such as a selector magnet, the current response, which is the parameter that relates to the force applied to the selector armature, is distorted (**fig. 3**). Since the time constant ΔT is determined by dividing the inductance by the total loop resistance, the following approximate relationship exists:

$$D = 100B\ L/R = 100BLI/V$$

where R = total loop resistance (ohms)
L = inductance (henries)
I = closed-loop current (amperes)
V= open-loop voltage (volts)

A typical selector magnet (L = 700 mH) will generate (a) less than 2 percent of spacing bias when a 120 Vdc battery is used in a 60-mA, 45-baud loop, and

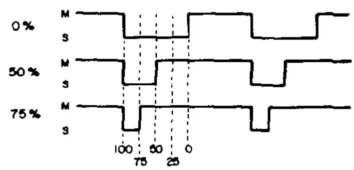

fig. 2. Degrees of marking bias.

(b) nearly 15 percent of spacing bias when operated at 13.2 volts (the minimum amount capable of supplying the 60-mA current through a 110-ohm coil).

Keying relays. When properly adjusted, relays can be useful in controlling dc loop circuits. The inability to follow fast keying pulses instantaneously causes relays to introduce significant delay to RTTY pulses – but this delay need not generate bias distortion if applied equally to making and breaking events.

Polar relays meet this requirement, but their use should be limited to cases where adequate instrumentation is available to keep the relays adjusted properly. Reed and mercury-wetted relays are sufficiently stable to requre no adjustments, but their selection must be accompanied by care in design since the make and break times of these relays almost always differ. **Fig. 4** shows one way to compensate these devices. R1, C1 are selected to protect the contacts but may introduce some marking bias. CR1 protects the transistor from over-voltage when the relay coil is switched off. Increasing R2 will decrease marking bias, while increasing R3 will decrease spacing bias. This latter operation may require a higher A+ voltage or lower coil voltage.

FSK keyers. Bypass capacitors are a requirement in the design of FSK keyers, but care must be taken to ensure that the dc time constants of the keying circuit

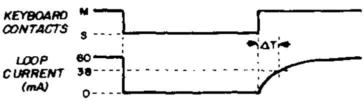

fig. 3. Spacing bias due to low loop battery voltage.

are small compared with the signaling unit time (1/B). An FSK keyer that works *fine at 60 wpm may present* excessive bias distortion at 100 wpm.

Transmitting contacts. Some transmitting contacts, such as the Model 14TD and Model 32, have accurate, distortion-free distributors when properly operated. Model 28 keyboards and TDs require careful setting of a single adjustment screw to eliminate bias and normally generate only minute end distortion. Models 14, 15 and 19-series keyboards, however, can generate large amounts of bias and end distortion when any of the six contact springs are improperly adjusted, as shown in **fig. 5**.

Speed error. The start-stop signaling system used in RTTY will tolerate nominal speed error. One way to look at speed differential is as if it were distortion that gradually increases as the signal progresses toward the end of each character. A page printer, for example, will react to a perfect signal sent too slowly, as if that signal had a distribution of spacing bias and marking end distortion.

FSK demodulators. One of the most severe causes of distortion can be the FSK demodulator. In some cases some of this distortion can be traced to poor design or adjustment in input, channel, or low-pass filters. The designer, for example, may have paid too little attention to phase response and the filter will have excessive overshoot and ringing. These situations generally will produce bias distortion, along with lesser amounts of end distortion, that are due to time constants and settling times in excess of one unit time (1/B). Such distortion often varies widely, depending on the characters received.

receiving considerations

The most limiting form of received distortion is generated by noise, interference, and signal fading. Each dB of improvement in this area calls for increased complexity and refinement. However, an occasional error will occur even with the strongest signals. Since noise can occur at any point on the signal waveform, a high probability of all types of distortion can be expected. To perform best with this random type of distortion, the receiving teleprinter should sample each signaling unit as close as possible to

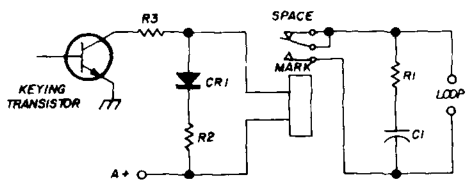

fig. 4. One way to compensate a nonpolar keying relay. Similar techniques can be used to compensate a transistor-keyed selector magnet.

its center. In practice, each receiving RTTY device must be adjusted for a maximum, but balanced, response to each of the four pure distortion types.

distortion test equipment

Common test equipment can be used for a few distortion measurements when specialized equipment isn't available. A Model 15 keyboard may be adjusted, for example, with an overdamped vom as follows.

Connect the vom across the keyboard in the low-ohms position to minimize the effect of the filter network. Adjust the ohms potentiometer for full-scale. Observe the 0 to 10-volt scale. Check that the meter reads 0 volts when the keyer contacts are open. Now turn on the motor and cause the clutch to engage steadily for repeated sending. Encode the BLANK symbol and adjust the stop spring for a reading of 1.92 volts. Now encode the characters E, LF, SPACE, CR and T, one at a time, while adjusting springs 1 through 5 for 3.26 volts.

The Model 28 signal generators may be adjusted similarly by repeat sending of the character R and adjusting for a reading of 4.62 volts.

A general-purpose oscilloscope with a triggered sweep may be used to analyze pure bias distortion; thus, it can be useful in adjusting relays, Model 28 contacts, and for resolving many other problems. A general-purpose scope is of little value, however, in the measurement of end distortion or bias in the presence of end distortion. This is because an ordinary scope won't synchronize on only the start pulse unless the sweep rate is adjusted for

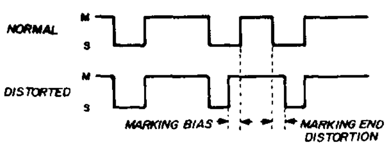

fig. 5. Bias and end distortion on the letter J from a Model 15 keyboard with a misadjusted number 4 contact spring.

one sweep per character, in which case the resolution is not sufficient to read distortion with meaningful accuracy.

special-purpose test gear

One of the best types of distortion test sets for RTTY received-signal analysis is the Western Electric 164C. This instrument has a special-purpose scope display calibrated linearly from 0 to 50 percent. The display is idle when no signal is present, and, after encountering a start pulse, a waveform generator causes seven horizontal linear transistions across the screen at the same rate in both directions (**fig. 6**).

The vertical deflection plates are fed from the input signal through an RC network that causes a mark-going bias edge to appear as a pip above the scope centerline and a space-going end-distortion edge to appear as a pip below the line. Marking and spacing distortion

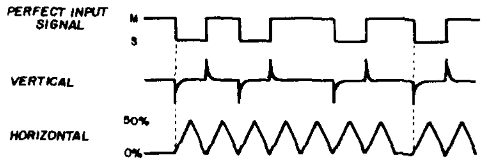

fig. 6. Typical waveforms for received distortion test sets of the type similar to the Western Electric 164C.

may be determined by the sweep direction at the time of the distorted edge, as shown by the shape of the pip. Typical sample signals are shown in **fig. 7**.

This type of instrument is ideal for setting up transmitting contacts, polar relays, and for optimizing demodulator design. Also, since it reads directly on any received message at either tape or keyboard speed, it may be used to analyze received RTTY signals during normal station operation.

test-message generator

Another useful instrument is the test-message generator. The best of these will generate a complex message consisting of all possible characters, with switched capability for accurate generation of the four types of distortion. Some units, like the Teletype DXD-100, combine the ability to generate a fox message with continuously variable distortion to 100 percent, with a stroboscopic display that may be used to adjust transmitting contacts. This instrument isn't very useful for received signal analysis, however, unless the incoming message is at tape speed and exactly at the same speed as the test set.

These distortion-generating test sets allow optimization of receiving teleprinter equipment. The best procedure is to print the test message while gradually decreasing distortion until perfect print is obtained for one or two lines. This procedure is repeated four times, once for each distortion type. The amount of tolerance to each distortion type should be logged, along with the position of the range finder on the teleprinter under test.

The procedure described is repeated for several different range positions until the best balance of distortion tolerance is obtained. That range setting is then locked into the machine and the worst-case distortion tolerance evaluated. Machines not able to tolerate, say, at least 35 percent of any type of distortion without errors at this final range setting may need adjustment or lubrication. Model 28 machines typically tolerate over 40 percent of any type distortion.

Many other types of distortion test sets are available. Some have peak-reading meter readouts; others have digital distortion displays. Each can be a useful addition to the RTTY station.

regenerative repeaters

The regenerative repeater, once a troublesome vacuum-tube device, can now be built easily with only a few integrated circuits. Regenerative repeaters receive the incoming signal from the demodulator and regenerate a perfect signal, which is fed to the teleprinter. Since the highspeed ICs can sample 50 percent of the time with great accuracy, generally no range adjustment is necessary. These circuits can often be used to increase the distortion tolerance of the printer, while easing the requirement for accurate range adjustment on the teleprinter.

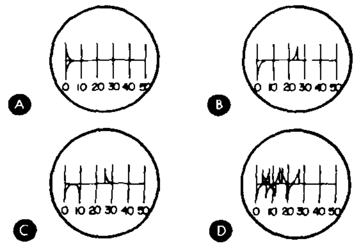

fig. 7. Perfect signal (A). 25-percent pure marking bias (B). 25-percent spacing bias plus 10-percent spacing end distortion (C). Demodulated signal received in the presence of noise, including random distortion peaking at 25 percent (D).

Probably the most essential requirement of a regenerative repeater is an accurate time base, stable with temperature (preferably crystal controlled), and capable of jitter-free start-stop control. Where these conditions can be met, the regenerative repeater is well worth installing as part of the FSK demodulator.

conclusion

The need for measuring and eliminating the various forms of pulse distortion have been around for as long as people have been communicating with Morse code. Telephone companies have elaborate test stations to maintain landline telegraph systems. Many of the procedures developed over the years can help make a science out of a situation that may have meant nothing but unexplained and irritating errors to many RTTY amateurs.

ham radio

"And two large barrels, a coil of copper tubing, kerosene burner, two dozen jugs. . ."

advanced divide-by-ten frequency scaler

This simple 10:1 prescaler will increase the frequency range of your counter to 300 MHz

F. Everett Emerson, W6PBC, 1709 Notre Dame Avenue, Belmont, California 94002

A ten-fold increase in the range of many frequency counters is possible with the use of the simple 10:1 prescaler of advanced design described here.

Frequency measuring systems, some simple, some highly sophisticated, have stirred the interest of hams for many years, but never more enthusiastically than in recent years when digital frequency counters have become available. The usefulness of such systems in the ham shack and workshop has made them exceptionally popular. Indeed, their popularity has become so widespread that frequency counters are even available in kit form.

Since becoming intrigued by frequency-measuring counters about two years ago, I searched through the ham literature for articles on counters and counter accessories.[1,2] In addition, two Heathkit counters were closely observed and their frequency limits and sensitivity were carefully noted.* K4EEU's divide-by-ten scaler, using four ICs, was constructed; when used ahead of the Heathkit counters, it permitted measurements up to 106-MHz. This appeared a worthwhile combination. In fact, it was a very happy combination which sufficed until Heathkit came out with its preassembled 80-MHz counters and a 175-MHz scaler kit.[3]

Then, dissatisfaction with the 106-MHz setup quickly took hold. As an end result, a 9-digit counter was built which had an upper frequency limit that turned out to be 125-MHz. A search was then made for a better scaler to further extend this upper limit.

My attention was drawn to Fairchild's 9500 series high speed, emitter-coupled

*While Heathkit advertises a frequency limit of "over 15 MHz," both counters measured well above 15 MHz, one reaching 25 MHz, and one reaching 30 MHz.

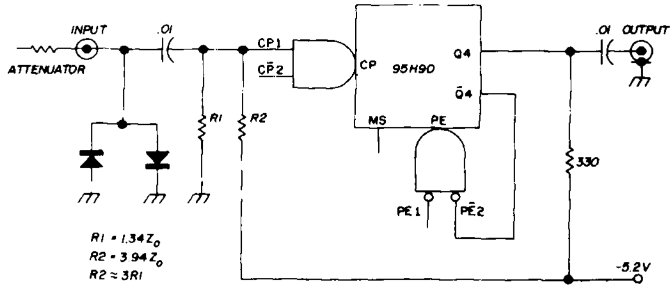

fig. 1. Logic symbol and connections to the Fairchild 95H90 IC used in the 300-MHz prescaler.

logic (ECL) integrated circuits. Among them is their 95H90, a very high speed, temperature compensated, ECL circuit for frequency division. This is a divide-by-ten prescaler usable to about 300-MHz. For the owner of a counter whose upper frequency limit is on the order of 25 to 30 MHz, such a prescaler would permit measurements in every amateur band up to and including the 220-225 MHz band. The prescaler described here will do that and more. It should prove to be especially attractive to the vhf enthusiast.

circuit

Three prototype prescalers have been constructed using the Fairchild 95H90 for ten-to-one frequency division. As constructed (one hard-wired bread board and two one-sided foil circuit boards), their lower limits for sine-wave inputs were found to be between 6 and 9 MHz and their upper limits were between 220 and 272 MHz. These variations are apparently due to slightly different construction techniques, types of component capacitors used and possible variations in the ICs. All, however, were decidedly successful and exceedingly stable.

Since the output is a square wave, the output will be accepted by practically any counter. In this connection, it should be noted that the output is deliberately made through a dc-blocking capacitor, a *must* if the divice is to be used ahead of the Heathkit counters whose inputs do not have one.

The Fairchild 95H90 is a high speed ECL MSI device, designed specifically for the communication and instrumentation industries. All of the high-speed logic manipulations are "on chip." In this single, 16-pin, dual-in-line IC package, frequency division by ten may be quite simply accomplished and at a lower over-

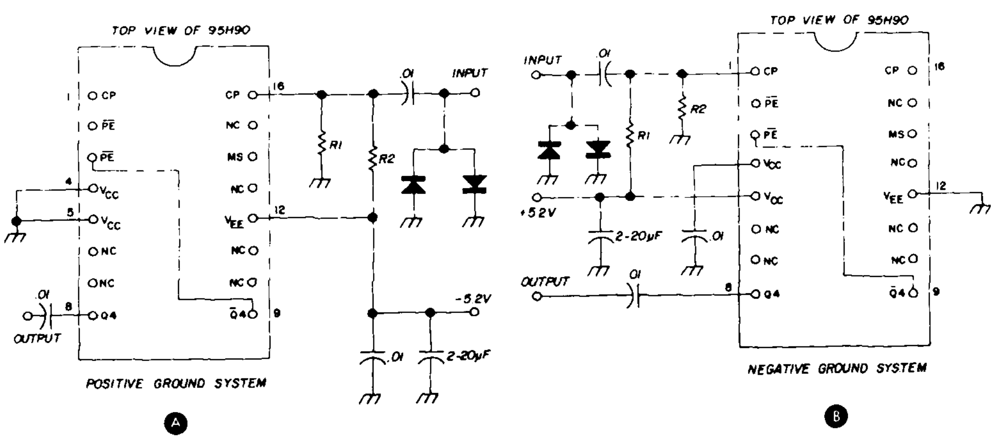

fig. 2. Complete schematic of the 10:1 prescaler. Circuit in (A) is for positive ground. Circuit in (B) is for negative ground. For 50-ohm input, R1 = 68 ohms and R2 ≈ 200 ohms.

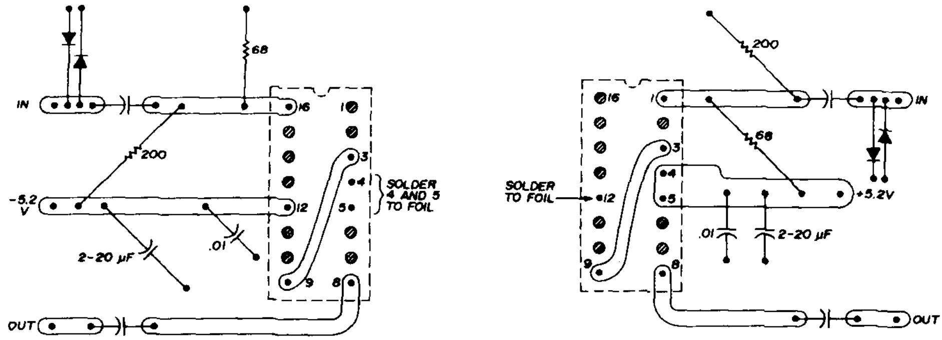

fig. 3. Circuit-board layout for the prescaler is extremely simple. Layout in (A) is for positive ground; (B) is for negative ground.

all cost than scalers using a multiplicity of ICs which divide by two, and then, by five. Although the 95H90 may be so connected to divide by eleven, and with other control logic a divide-by-N counter can be constructed, these uses are not of concern here; only the divide-by-ten connection will be considered.

The 95H90 prescaler logic symbol and its necessary external components are shown in **fig. I.** A well-filtered and regulated 5-volt power supply is required. Resistors R1 and R2 set the input bias and are in the ratio of R2 equaling approximately three times R1. These resistors also partially determine the IC's input impedance, and are specified as R1= 1.34Z, and R2= 3.94Z. Thus, for a 50-ohn input, R1= 67 ohms and R2= 197 ohms. For practical usage, R1 may be 68 ohms and R2 may be 200 ohms for an input impedance of 51 ohms.

The schematic of the 10:1 prescaler is shown in **fig. 2. Fig. 2A** is for use where the positive supply voltage is connected to the circuit board foil (positive ground), while **fig. 2B** shows the connections where the supply negative is connected to the board foil (negative ground). Fairchild specifies the positive ground; however, each connection (positive or negative) has been tried on separate prototype boards with no discernable ill effects on the device's frequency limits. The negative ground seems to be preferred by amateurs. Note that **fig. 2** shows top views of the 95H90, in accordance with the practice of the IC industry.

construction

Circuit-board layout, showing bottom views (foil side), are shown in **fig. 3** The simplicity of these layouts should be readily apparent. For those who can make them, etched boards are ideal. Because of the circuit simplicity, however, the prototype boards were made by first drawing enclosing lines on the boards with a marking pen and then gouging away the lines with a hand-held

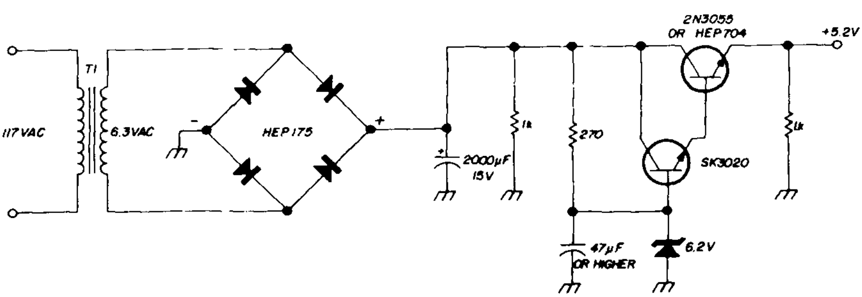

fig. 4. Power supply for the prescaler provides 5.2 Vdc output.

hobby-type burr drill, a process which took about five minutes. For a neater job, lines may be readily removed on a drill press.

In any event, the prototype method proved so acceptable that one of the original boards is now in permanent use. **Fig. 3A** shows the positive ground, while

200 mA. Fairchild's 95H90 data sheet specifies a 5.2-volt supply. The power supply voltage tolerance should be held within plus or minus 5% of 5 volts.

One prototype prescaler optimized at 5.2 volts and another at 4.8 volts; how-

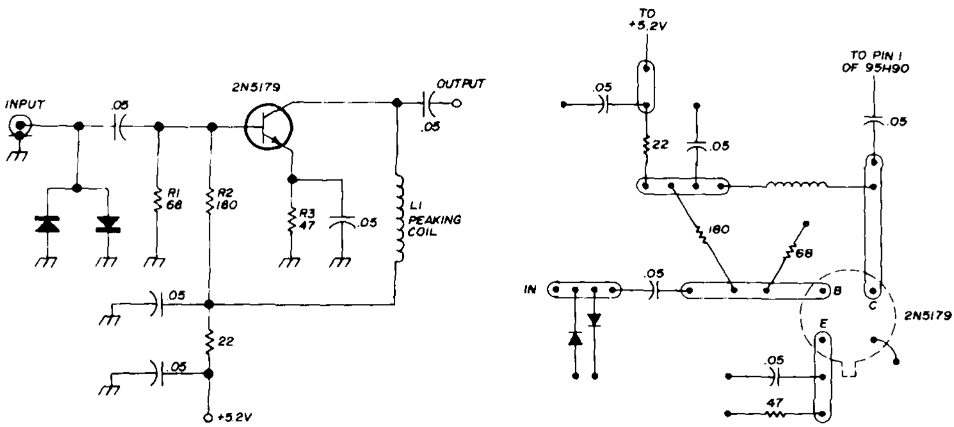

fig. 5. Simple preamplifier circuit increases sensitivity of prescaler. Peaking coil L1 is 8 turns no. 26, 5/32" diameter, air-wound, spread to cover 5/8" length. Circuit-board layout is shown to right.

fig. 3B shows the negative ground.

Half-watt resistors were used because of their ready availability. Quarter-watt resistors would permit an even smaller layout. Capacitors should be of the best quality. The .01-μF capacitors should be ceramic discs because these types offer lower impedances than other types. The large bypass capacitor (2 to 20 μF) should be a tantalum type. If a tantalum capacitor is not available, use a physically small electrolytie.

In one prototype a 10-μF, foreign-make, electrolytic was used, along with Mylar-type .01-μF capacitors, without deterioration of more than a few MHz in the upper frequency limit.

Note the protective diodes at the prescaler input; use the fastest diodes you can obtain. They are a cheap way to save a moderately-expensive 95H90.*

A suitable power supply is shown in **fig. 4**. Ready availability of parts determined its capacity, not the need for large currents. The prescaler draws less than

ever, the standard supply is 5.2 volts and will service numerous ICs. Remember that the output voltage will equal the zener voltage minus the drop in the two transistors. Thus, with a 6.2-volt zener, the output will be 5.2 volts.

sensitivity

The sensitivity of the prescaler prototypes varied from approximately 130 millivolts at 100 MHz to 240 millivolts at 260 MHz. This is adequate for many uses. For greater sensitivity, however, a single transistor preamplifier may be added. A schematic of a wideband amplifier, using a 2N5179 transistor, which is suitable for use with this prescaler, is shown in **fig. 5**. Normal vhf construction practices, such as the shortest possible leads and ade-

*When ordering the 95H90 IC, specify the Fairchild U6B95H9059x. Circuit Specialists, Box 3047, Scottsdale, Arizona 85257 has all the semiconductors for this unit in stock. The 95H90 is $16.00, the 2N5179 is 50 cents, the HEP 704 (2N3055) is $2.50 and the HEP 175 is $1.35. Please add 35 cents for shipping.

quate decoupling, are needed.

If this preamplifier is used with the prescaler, R1 in **fig. 2B** should be changed to 4700 ohms, and R2 should be changed to 1500 ohms. Preamplifier sensitivity will range from about 15 millivolts at 100

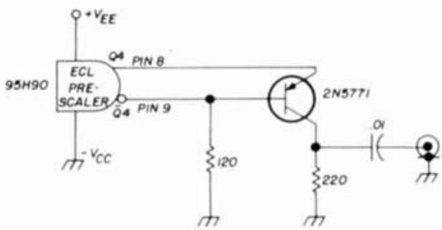

fig. 6. Post amplifier circuit for use only if counter has insufficient sensitivity or if a TTL interface is required.

MHz to about 100 millivolts at 220 MHz. All in all, a worthwhile addition.

If your present counter is deficient in sensitivity, a simple single transistor post-amplifier may be added to the prescaler. Its schematic, using a 2N5771, is shown in **fig. 6** for a negative-ground supply. However, a counter which would not respond to this prescaler is yet to be found. If, by chance, yours does not, it's high time to find out what is wrong with your counter. The amplifier shown in **fig. 6** makes an excellent interface if such is desired for connection to a following TTL device.

This article could not be considered complete without expressing sincere appreciation for the valuable assistance and checking of the devices by Robert Melvin, W6VSV. I am deeply grateful for his help and his enthusiastic support.

references

1. Bert Kelley, K4EEU, "Divide-by-Ten Frequency Scaler," *ham radio*, August, 1970, page 26.
2. Kenneth Macleish, W7TX, "A Frequency Counter for the Amateur Station," *QST*, October, 1970, page 15.
3. Factory-built Heathkit 80-MHz counters include the model SM-104A ($540) and the model SM-105A ($375). The Heathkit 175-MHz scaler kit, model IB-102, sells for $112.95.

ham radio

repeater control with simple timers

All-electronic timers provide reliable, simple and inexpensive repeater control

George R. Allen, W2FPP, and Richard J. Sobus, K2QLE

Repeater activity is increasing daily, and it seems that there is always need for one more repeater in town. Unfortunately, installing a repeater usually turns out to be quite a difficult project, and for every operational repeater on the air there are probably ten more that will never make it. The unfinished repeaters usually run into many roadblocks, one of which is the problem of designing and installing the necessary controls such as delay timers, three minute timers and repeater ID timers.

From our experience, it appears that a lot of the repeaters today are using mechanical timers with their inherent disadvantages of high cost, inadequate reliability, large size and susceptibility to adverse environmental conditions. The timers described in this article were designed to provide a means for eliminating the roadblocks caused by using the con-

Printed circuit boards for the repeater control unit are available from Alton Industries, 7471 Thunderbird Road, Liverpool, New York 13088. *Drilled boards are $4.50, undrilled* boards are $3.50. Included with the boards is a detailed schematic and board layout. Wired and tested units are available from the same source for $33.50.

ventional approaches to timers. These timers are highly reliable, simple to build, very inexpensive and can be connected together to provide repeater control without need for mechanical contacts. This article also shows the complete interconnection of these timers to form a repeater control unit.

The two timers shown are based on the same principles; however, there is one basic difference. The timer in **fig. 1** will deliver one output pulse *after* a given time interval, while the timer in **fig. 2** will deliver the output pulse *before* the time interval. In both cases, only one output pulse can occur for each time interval regardless of the number of input pulses. In both cases, the timing cycle will not repeat unless an input pulse is received.

timer operation

When power is first applied, C1 begins to charge through R1 until the emitter of Q2 reaches approximately 6 V. At that time the 2N2646 unijunction fires, resulting in a positive pulse across the 33-ohm resistor. This pulse is inverted to a negative going pulse by Q3. With the constants shown, the approximate timing cycle is two minutes and ten seconds. A 2N2647 is a more desirable unijunction, but the 2N2646s were on hand and gave satisfactory performance.

In the circuit of **fig. 1**, the output pulse triggers a set-reset flip-flop which turns the timer off. The timer will be started again by grounding the reset line of the S-R flip-flop. The *timer reset* is used to set the timer to its initial state. It will do this even if the carrier-operated relay is closed. Its main function is to reset the timer if it is not desired to complete the timing cycle.

In the circuit of **fig. 2**, the output pulse sets the S-R flip-flop which then results in a +5 V level at pin 5 of the NAND gate U1B. In order to get an output from this timer, a zero volt output is required at pin 6 — this output can be obtained only when both inputs are at a

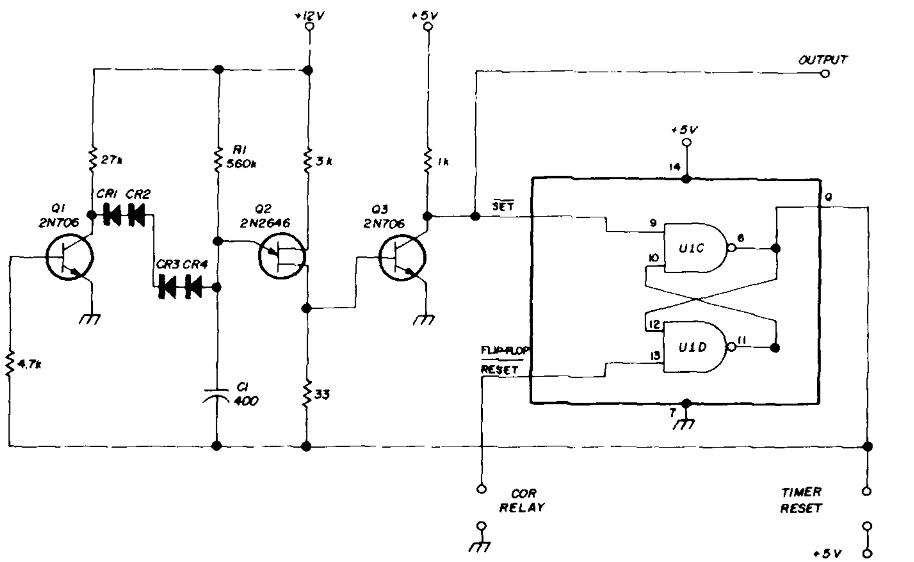

fig. 1. Basic timer to give one pulse after a given time interval. U1 is a 7400 IC. CR1 through CR4 are silicon diodes. R1 and C1 can be changed to provide different timing intervals.

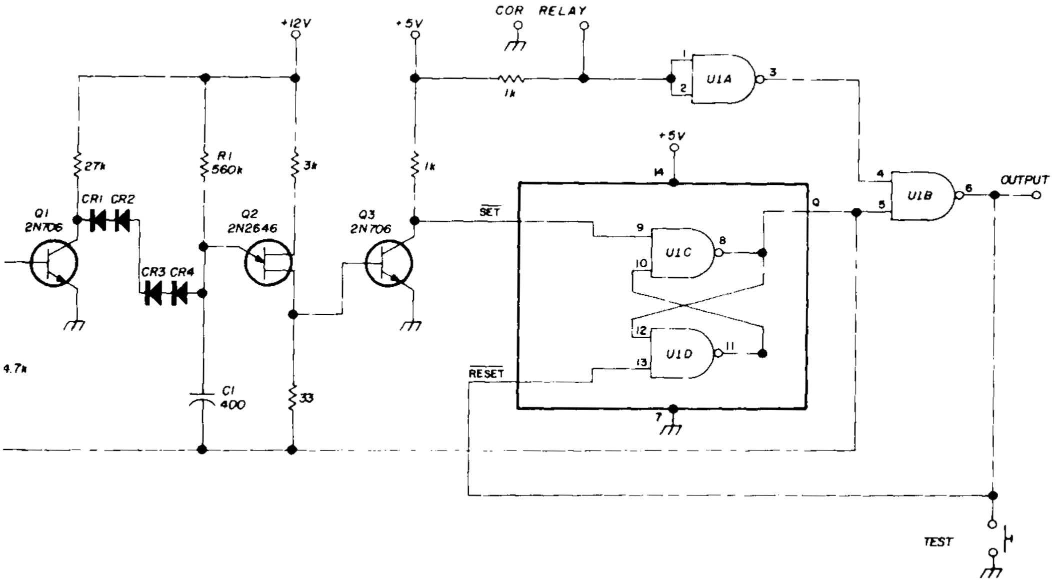

fig. 2. Basic timer to give one pulse before a given time interval. Other notes are the same as in fig. 1.

+5 V level. As connected, U1A is an inverter which has a zero volt output when the input is open and a +5 V output when the input is grounded. Therefore, when the input is grounded, both inputs to U1B are +5 V, the output goes to zero and the flip-flop resets. The resultant output is a pulse at the beginning of the timing interval. With this timer, an output can occur only when the COR contacts are closed. Thus, if this timer is used for an identifier, the ID will trigger only when the repeater is active.

timer applications

The timer in **fig. 1** can be used as the

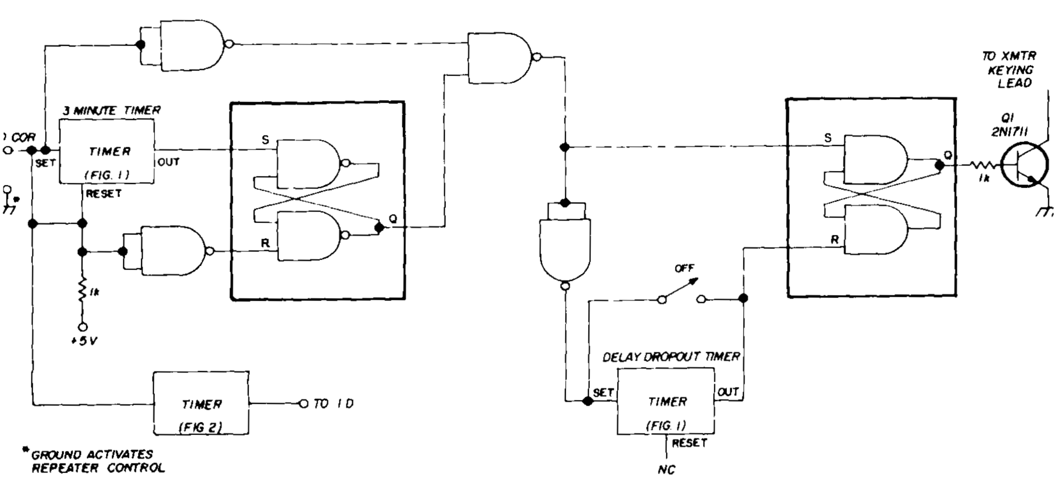

fig. 3. The complete repeater control unit. The gates are all parts of 7400 integrated circuits.

three-minute timer for a repeater by selection of the proper value of C1. The input can be the contact closing of a carrier-operated relay, while the output pulse can trigger a simple S-R flip-flop which will disable the transmitter. Thus, if the COR is on for longer than the specified interval, the transmitter will be timed out. This timer can also be used to provide a drop-out delay for the transmitter. In this case, the absence of carrier will trigger the timer and the resultant delayed pulse will cause the carrier to drop out.

The timer in **fig. 2** can be used to trigger a repeater identifier. In this mode of operation, the ID will only go on at the beginning of a timing cycle. If the repeater has been inactive for longer than the timing interval, the ID will be keyed up when the COR is keyed, and the ID will be keyed every two minutes and ten seconds as long as the COR is keyed. The ID cannot be keyed unless the COR is keyed, thus eliminating the problem of the ID keying up the repeater when there is no activity.

repeater control unit

The interconnection of the timers to provide a complete repeater control with a three minute timer, a drop out delay timer and a repeater identifier timer is shown in **fig. 3**. The entire circuit as shown was used at the WA2ZVZ repeater until it was replaced recently by a commercial unit with telephone-line remote-control capabilities. The ID timer portion, however, is still in use. There have been no failures of this timer with temperatures ranging from sub-zero to 80 degrees. The only phenomenon noticed was a decrease in the timing cycle amounting to about five or ten percent during extremely cold weather.

The circuits presented in this article are reliable, simple to build and inexpensive. it is hoped that these circuits will help many repeaters become operational by overcoming some of the problems relating to timers and repeater control.

ham radio

solid-state hang agc circuit for ssb and cw

A high performance solid-state hang agc circuit for use with fet and mosfet rf circuits

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In the rather distant past, when amateur radio operators depended upon a-m for communications, automatic gain control in the receiver was a simple matter. The negative dc voltage necessary for agc was easily derived by sampling the output of the diode a-m demodulator. This negative voltage was fed to the grids of the rf and i-f amplifier tubes to maintain a constant detected audio level which varied only slightly as the signal faded or as various stations were tuned in, and was also used to control the S-meter. Due to the presence of a carrier, agc circuits for a-m were relatively simple. Subtle factors such as attack and decay time could be comfortably ignored. The CW gang, purists that they were, happily rode the manual rf gain control while they pounded brass.

Single sideband brought an end to these happy days, and in the few cases where the local bfo signal did not pin the S-meter, the absence of a carrier during periods of no modulation caused S-meters to flop erratically. With the introduction of product detectors, which kept the bfo signal away from the agc detector, gain-control circuits were used which permitted fast rise and slow decay of the dc output. However, to hold the agc level and receiver gain reasonably constant between voice syllables or code characters, the decay-time constant had to be so long that receiver gain did not respond quickly enough to *signal-level changes* experienced with fading signals or roundtables.

A nearly ideal ssb and CW agc circuit

was introduced by W1DX in 1957.[1] This circuit separated the agc line from the "clock" which controlled the hold time. This development, dubbed *hang agc*, allows the agc line to remain at a steady negative voltage following a voice syllable or code character; the "clock" counts off a predetermined time, after which it triggers a discharge circuit which rapidly restores the receiver gain to maximum in the absence of a signal.

The W1DX circuit requires three diodes, one triode and a voltage step-up transformer along with some resistors and capacitors, and its power and space requirements are substantial. Nonetheless, it has been used to supply audio-derived

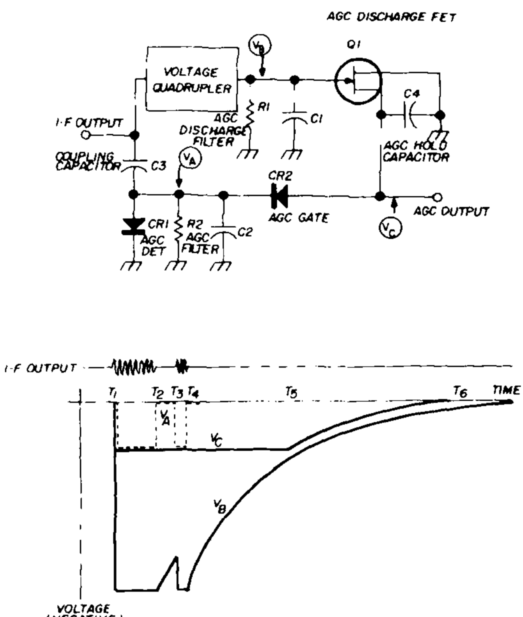

fig. 1. Basic solid-state hang agc circuit and dc voltage levels at different times in the operating cycle.

performance has easily justified the extra parts. Since a high-impedance agc line is necessary for the hang circuit, it does not interface well with bipolar transistorized receivers unless a buffer amplifier is used.

The recent popularity of field-effect rf and i-f amplifiers, particularly those using dual gate mosfets, has revived the high-impedance agc line. The circuit described here is an all solid-state version of W1DX's hang agc system which is small, inexpensive, requires no external power and can be used with either tube or fet rf amplifiers. It operates directly from the i-f strip, avoiding the minor difficulties which occur in many audio-derived agc systems.

table 1. Hang and discharge times for the circuit of fig. 1. Times are in seconds for resistance in megohms and capacitance in microfarads. Vp is the pinch-off voltage of Q1.

$\frac{V_A}{V_P}$	hang time (T5-T4)	discharge time (T6-T5)
0.5	0.29 R1C1	0.41 R1C1
1.0	0.69 R1C1	0.69 R1C1
2.0	0.98 R1C1	1.1 R1C1
4.0	1.16 R1C1	1.61 R1C1
10.0	1.29 R1C1	2.40 R1C1
20.0	1.34 R1C1	3.05 R1C1
40.0	1.36 R1C1	3.71 R1C1

basic circuit

Fig. 1 shows the basic circuit and the dc voltages at various stages of its operating cycle. When a signal appears at the i-f output at time T1, it is rectified by CR1, filtered by R2C2, and gated as a negative voltage onto the agc hold capacitor C4, and the agc line. Simultaneously, a negative voltage four times greater than the agc level is developed across C1 which prevents Q1 from conducting. When the signal is removed at time T2, voltage V_A rapidly drops to zero. However, the agc line voltage, V_C, does not drop because Q1 is off, CR2 is reverse biased and the agc line has no dc return to ground (resistance to ground should be greater than 100 megohms for the circuit to work properly). Capacitor C1 begins to discharge through resistor R1, causing the gate voltage of Q1 to drop. Before Q1 can conduct, however, the signal reappears at time T3, recharging C1, C2 and C4.

Following the disappearance of the signal at time T4, V_A drops to zero and V_C, the agc level, remains constant while V_B *decays with the time constant* R1C1. At time T5, the negative gate-source voltage of Q1, V_C-V_B, has reached the pinch-off voltage of the fet, V_P or $V_{GS(off)}$, and Q1 conducts, discharging the agc hold capacitor. The agc line goes to zero volts in the time interval T5 to T6.

Reviewing the operation of the circuit, CR1, R2 and C2 maintain a negative dc voltage, V_A, which instantaneously follows the envelope of the i-f signal. The agc gate, CR2, allows the hold capacitor, C4, to charge up to the peak value developed across C2 and to hang at that value after the signal decreases in amplitude. The voltage quadrupler maintains a voltage V_B, approximately four times V_A, which biases Q1 into cutoff. Voltage V_B rises very fast when a signal appears, but decays quite slowly after the signal disappears. This slow decay, with time constant R1C1, is the "clock" that controls the hang time (the interval T5-T4 in **fig. 1**). After the prescribed amount of "clock" time has elapsed, the agc line is discharged if there is no signal, and the receiver returns to maximum gain.

By properly choosing the RC time constants in the circuit, receiver gain is quickly reduced as a signal appears (no unpleasant thumps caused by slow attack time constants). The gain then stays absolutely constant between voice syllables or code characters (the S-meter doesn't even wiggle), but recovers rapidly enough after the hang time to follow fading signals or weak stations in a roundtable.

The circuit has an intrinsic threshold, below which weak signals and noise will not activate the agc. The threshold level is approximately one volt, and is equal to the forward drop of CR1 (0.7 volt) plus $V_P/4$, (V_P is the pinch-off voltage of Q1). Although the hang and discharge times of the circuit depend slightly on signal level, the variations are scarcely noticed during operation. Exact values are given in **table 1**.

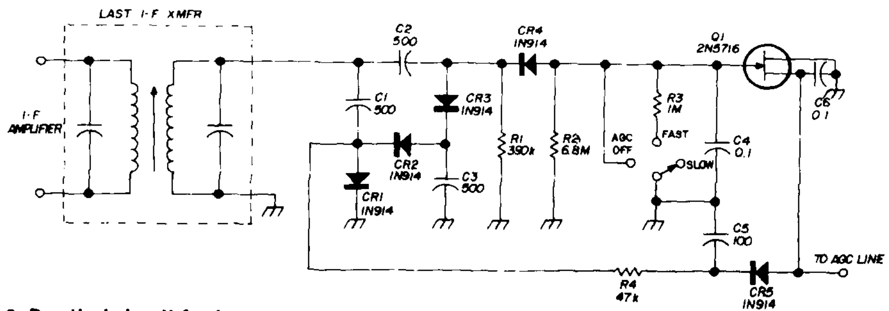

fig. 2. Practical circuit for hang agc.

practical circuit

A working hang agc circuit with a total parts cost less than $4.00 is shown in **fig. 2**. Diode CR1 is the agc detector whose attack time is controlled by C1 and the source impedance of the last i-f transformer. For reasonable source impedances of 10k or less, the attack time is shorter than 10 μsec. The decay time of the detected signal is also very fast, set by C1, C5 and R1 to 250 μsec.

The detected signal is gated onto the agc hold capacitor, C6, through R4 and CR5 with an attack time, R4C6, of 5

table 2. Dc voltages for the circuit of fig. 3.

test point	dc voltage
V1	-30 Vdc
V2	+4.3 Vdc
V3	+3.3 Vdc
V4	+12 Vdc
V5	+1.0 Vdc
V6	+30 Vdc

msec. This keeps C6 from being charged up by large, short-duration noise spikes. A negative voltage is developed by the voltage quadrupler, CR1-CR4, C1, C2, C3 and R1; this negative voltage is applied to the agc discharge fet, Q1. Resistor R1 causes the dc voltages across C1, C2 and C3 to decay with a 200-μsec time constant, allowing the quadrupler to recover quickly after removal of a signal. Hang time for ssb/CW operation is set at 0.7 second by R2 and C4, and can be reduced to 9 msec for a-m operation by placing R3 in the circuit. Agc is removed by shorting C4, which keeps Q1 in conduction at all times by grounding its gate.

All diodes in the circuit must be fast recovery types. In addition, they should have low reverse leakage currents. Diodes CR4 and CR5 are particularly critical in regard to high back resistance. Most silicon computer diodes will work well, but conventional silicon detector diodes, silicon rectifiers or germanium diodes should not be used. The 1N914 types called for in **fig. 2** are available at very reasonable prices.*

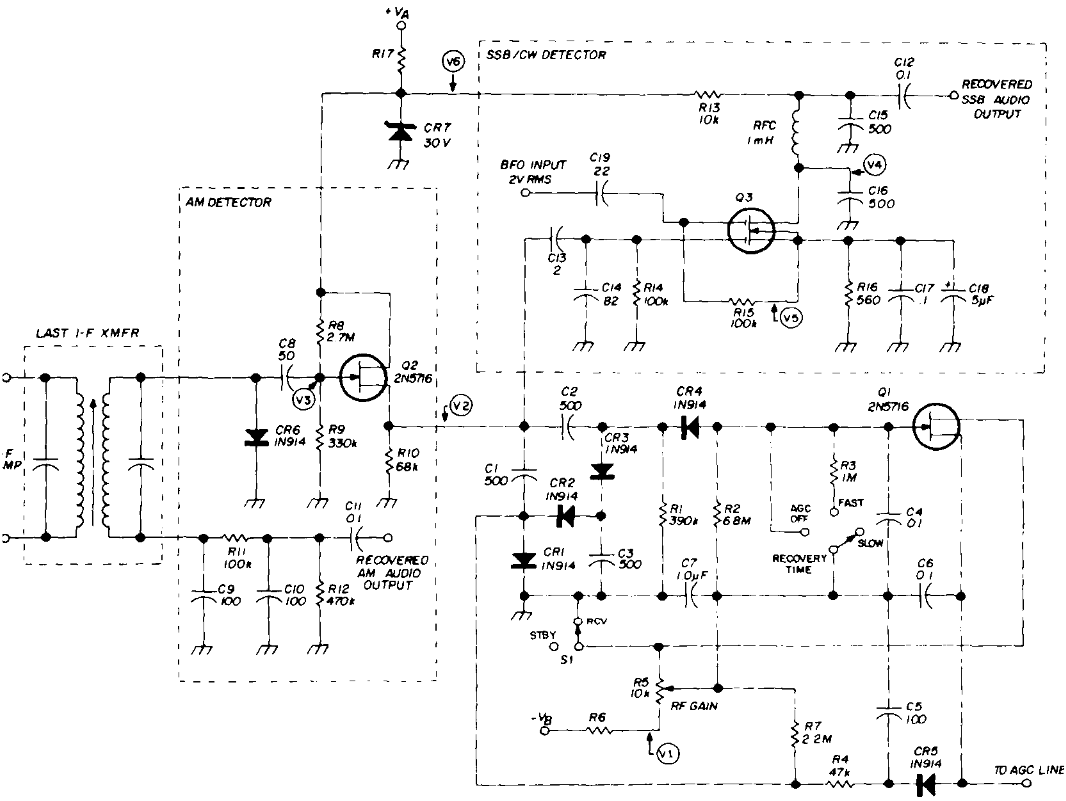

fig. 3. Hang agc circuit with a-m and ssb/CW detectors, manual gain control and disable feature for use when transmitting. Transistor Q3 is a Motorola MFE3008 or RCA 40604.

The choice of an n-channel fet for Q1 is considerably narrowed by the need for a device having a low pinch-off voltage. Most commercially available devices have rather large pinch-off voltages in the 3- to 10-volt range. However, the Motorola 2N5716, which is available from

*1N914 diodes are priced at 16 for $1.00 from M. Weinschenker, Box 353, Irwin, Pennsylvania 15642.

Motorola distributors for $.80, has a pinch-off range of 0.2 to 3 volts. In addition, the 2N5716 is rated for up to -40 volts on either the gate or the source with the drain grounded. Many other fets are breakdown rated at about half of this value, prohibiting their use in tube-type receivers where the agc voltage can easily go -10 volts during normal operation, or where the output of the voltage quadrupler applies -40 volts to the gate of Q1.

expanded circuit

Fig. 3 shows the basic circuit of **fig. 2** plus a number of features which add to the versatility of the hang agc circuit. **Table 2** lists the dc voltages which should be observed at the identified points. The cold ends of R2, R3, C4, C5 and C6 have been lifted from ground and connected to the wiper arm of R5 which feeds a negative bias to the gate of Q1, and, through R7 and CR5, to the agc line. A drain current of less than one microampere, flowing through R7, keeps Q1 near cut-off. Resistor R6 should be selected to give -30 Vdc at point V1.

This manual gain-control circuit is most useful since, along with reducing the gain of the receiver, it provides an agc threshold.[2] If the S-meter reads the agc bias in the normal manner, then its reading will increase as bias is manually introduced, and the threshold prevents stations weaker than the level indicated on the S-meter from operating the agc circuit.

The entire agc line is put on standby during transmit with S1. Switch S1 removes the ground from R5 and, since R5 and R6 no longer act as a voltage divider, the full voltage, $-V_B$, is applied to the agc line. Since V_B may be in excess of 40 volts, the breakdown rating of Q1, its drain is also biased to $-V_B$ during standby to prevent damage to the fet. Switching action may also be achieved by connecting a set of transmit-receive relay contacts in parallel with S1.

Diode CR6 is the a-m detector and its output is filtered by C9, C10 and R11. The action of agc rectifiers CR1-CR4 would severely distort the detected a-m signal if they were connected directly to the i-f transformer secondary, thus the source follower Q2 is used to isolate the agc circuit.

A product detector, consisting of Q3 and its associated components, is used for ssb and CW. The dual-gate mosfet isolates the bfo signal from the agc detector, preventing agc action in the absence of any signal. The capacitive divider, C13 and C14, reduces the ssb/CW output to a level compatible with the output of the a-m detector.

Zener diode CR7 reduces the supply voltage, V_A, to a level suitable for Q2 and Q3. Resistor R17 should be chosen so that about 3-5 mA is drawn from point V_A. If a 30 ± 5 volt supply is already available, it may be connected directly to the junction of R8 and R13. Then CR7 and R17 are not required.

installation

Wiring of the circuit is non-critical except for the usual observance of reasonably short leads in the portions of the circuit which carry rf. Various methods of feeding agc voltage are illustrated in **fig. 4**. Existing receivers probably will require little or no modification to use these systems. The only precautions necessary are to keep the RC time constants small, being careful to use R and C values no greater than those shown, to preserve the rapid attack time of the agc circuit. In all cases the S-meter amplifier should have dc gate or grid characteristics similar to the devices used for rf and i-f amplification.

It is important to keep leakage resistance from the agc line to ground greater than 100 megohms. Smaller values will discharge the line more rapidly than intended. The input impedance of most voltmeters is too low to measure the agc voltage. The S-meter should be calibrated as a voltmeter if you want to measure the agc voltage.

The circuit shown will not operate with low-impedance bipolar-transistor agc lines. Buffer dc amplifiers must be used in such cases or in situations where the agc line must have a finite resistance to ground. The design of such amplifiers is beyond the scope of this article, since each one must be uniquely related to the quiescent bias levels of the receiver it is used in.

The circuit of **fig. 2** is presently in use in my NC-125 receiver, while the system of **fig. 3** is functioning in my KWM-1. Reception of ssb or CW is excellent, with smooth agc attack and beautiful hang, followed by rapid recovery. It is impressive to watch an S-meter hold rock steady in the presence of a signal, yet quickly follow fading or the strengths of different signals while scanning the band. The hang agc system requires minimal space and power, and is inexpensive to build. Its use is highly recommended in new construction as well as in upgrading existing equipment.

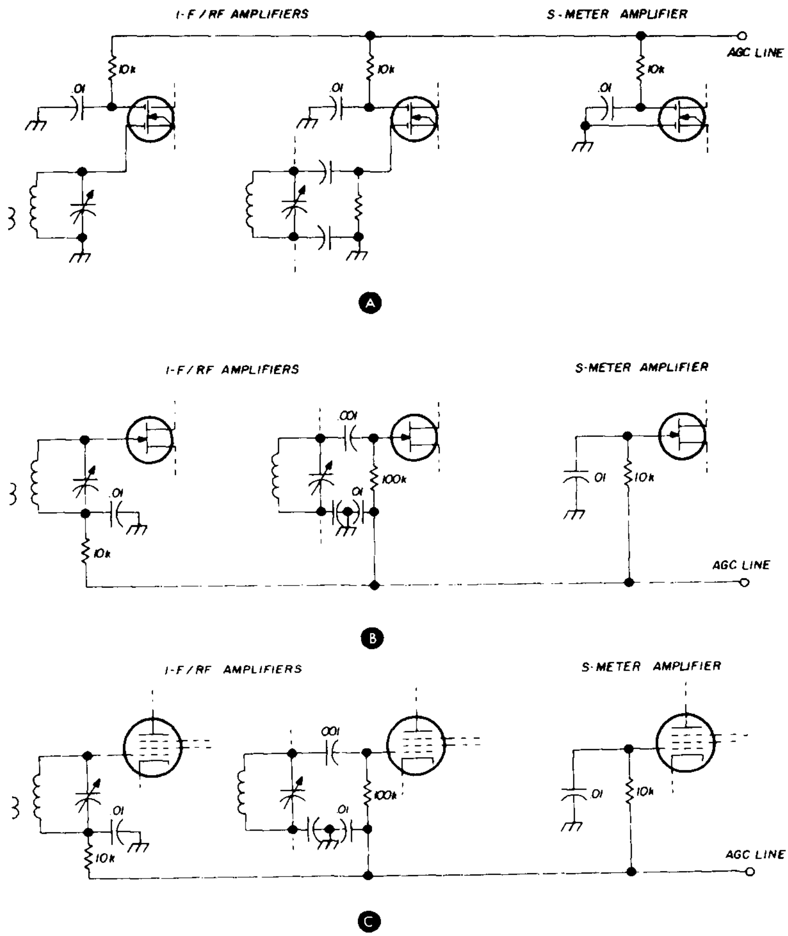

fig. 4. Typical agc distribution systems for dual-gate mosfets (A), jfets (B) and vacuum-tubes (C).

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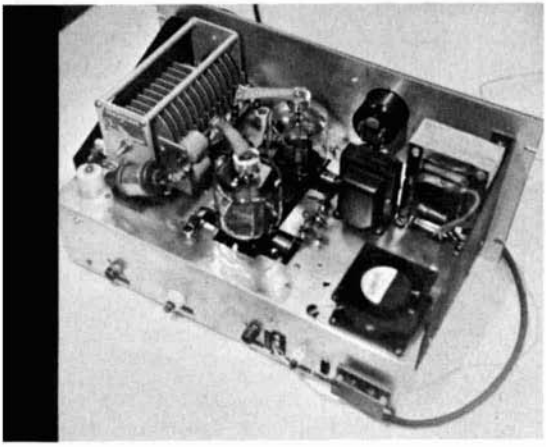


using odd-ball tubes in linear amplifier service

Practical suggestions for putting your surplus tubes to work

Carl C. Drumeller, W5JJ, 5824 N. W. 58 Street, Warr Acres, Oklahoma 73122

If you have been an active amateur for any length of time, chances are you've accumulated several transmitting tubes. Such tubes may be triodes or tetrodes of various lineage – generally they have large envelopes, husky filaments, and are capable of withstanding quite high plate voltage. A challenging question is, how do you use these tubes in today's ssb linear amplifiers? Essential information is difficult to obtain for operating older tubes in linears.* This article offers some suggestions on using older transmitting tubes in a clean-sounding linear amplifier even if you don't have manufacturers' data on the operating characteristics of such tubes.

operating considerations

The specifications for modern triode linears indicate that only very high-mu tubes, preferably those that operate with zero bias, will be satisfactory. There is no doubt that such tubes are somewhat easier to put into service, but tubes with just about any range of amplification factor can be made to perform acceptably. In fact, at one time tubes with very low mu were considered best for linear amplifiers because they would take a wider swing of grid voltage before drawing grid current.

Present-day practice, which centers about the grounded-grid circuit, largely ignores such fine points. The very heavy negative feedback inherent in the grounded-grid configuration tends to iron out distortion products resulting from the

*The ARRL handbook lists ratings for most transmitting tubes. Some of the older editions contain data on special "one of a kind" tubes from WW II. **editor.**

sudden transition from no grid current to full grid current. Also, the fact that the rf excitation *fed through* the amplifier tube tends to keep a swamping load on the driver stage further lessens the transition effect. So don't be concerned if that oddball transmitting tube in your junk-box has low or medium mu.

You can do quite well without knowing the mu. All you really need to find out is what bias, at the plate voltage you intend to operate, is required to hold the plate dissipation to an acceptable amount. But remember that most tubes found on surplus will take a very impressive voltage and will approach linear operation more readily when the plate voltage is near the upper limit. You can determine this parameter if you have (or can borrow) a variable-voltage power supply that provides several hundred volts. In addition, you'll need a voltmeter of similar range.

determining operating parameters

Let's assume you've built your amplifier to the point where you're ready to start testing with the intent of arriving at operating parameters. Initially, you set the grid bias at the highest negative potential available, then you turn on the plate voltage. If all goes well no plate current will flow: so you gradually reduce the grid bias, keeping an eye on the tube plate. Plate current will start to flow as the grid bias moves out of the cutoff region. As plate current goes higher the tube plate will start showing color. Here is where you'll have to use judgment. If the tube has a carbon plate, a dull red at the plate center is the stopping point. If the tube has a tungsten plate, a bit deeper red around the center of the plate is permissible. If the tube has a tantalum plate, the red glow can be permitted to spread over most of the plate.

When the reduced grid bias (and the resultant plate current) has caused the plate color you've decided to accept, quickly turn off the plate voltage. Turn it on again for just a moment, and note the grid voltage. Again turn on the plate voltage just long enough to note the plate current. From the plate current and the plate voltage, compute the plate power input. If it's not over *one-half* the amount of the tube's rated plate dissipation, you're at a good starting point.

power supply

Your next move is to construct a regulated power supply to provide the grid bias voltage you jotted down. A zener diode is highly recommended. Any number of zeners can be connected in series to provide the desired voltage. If you're planning to use two or more tubes in parallel, the grid current will increase in proportion, as will the plate current. After installing the zener-regulated bias supply, recheck to assure that the tube resting plate dissipation is still at the value you've elected to accept.

designing the amplifier

With your odd-ball tube you'll be on your own much more than if you follow some standardized design. Consider tube sockets for example. Many odd-ball tubes require sockets that won't be found in most supply houses. You may have to make your own, which I did for the Eimac 3A200A3 tubes in my amplifier. This job isn't too hard. Sometimes you can find a banana-plug socket that will fit tube prongs. I once used such components to make a socket for a Western Electric 212-E tube. Keep in mind that filament contacts must carry high current; therefore, the contact surface must be amply large and must make a firm connection.

tune up

For initial tune-up tests, it's best to use a dummy antenna. Only the final part of the test requires the radiation of a signal.

You've determined and set the values of plate voltage and grid-bias voltage. Now you must determine the proper excitation (as indicated by the grid-current meter) and the optimum plate-current loading.

Provide moderate grid excitation — just enough to resonate the plate circuit.

Now increase excitation and try loading the plate circuit. Remember to keep grid excitation to a moderate level. If you know the class-C grid current rating for the tube, keep the current below half this value. Adjust the plate circuit in small increments. Turn on the power and make quick adjustments, then turn off the power. Continue increasing excitation (but don't exceed the limit previously mentioned). Increase plate loading until the plate current dip becomes quite small. A better means of ascertaining the desired loading is with some device for measuring either the rf power output or voltage. When using this method, continue loading the amplifier until the rate of increase of output power (or voltage) approaches zero. Then back off the excitation about 10 percent.

You may wonder about a procedure that requires adjustments to be made quickly. The procedure is valid. You're adjusting for a maximum (peak) power, which will be reached only by random voice peaks. The duty cycle of such peaks is very small; therefore, they will not overload the tube. Your amplifier must handle these peaks without appreciable distortion else splatter will occur on either side of your desired signal.

on-the-air checks

For this test it's best to seek the cooperation of a station some distance away to avoid cross-modulation and intermodulation distortion in the receiver. Select a time and frequency when interference will be minimized. Also, try to have the cooperating station operated by someone who knows the difference between a clean ssb signal and one that is badly distorted. Do *not* depend upon a station having an oscilloscope attached to its receiver. Engineers who work with commercial ssb equipment have been quoted as saying, "Any distortion that can be detected on an oscilloscope already has gone far beyond the limit of tolerance." The instantaneous splatter that results from intermodulation products on the high-amplitude peaks of voice modulation can be detected only by listening on adjacent frequencies or by the use of an extremely expensive real-time spectrum analyzer.*

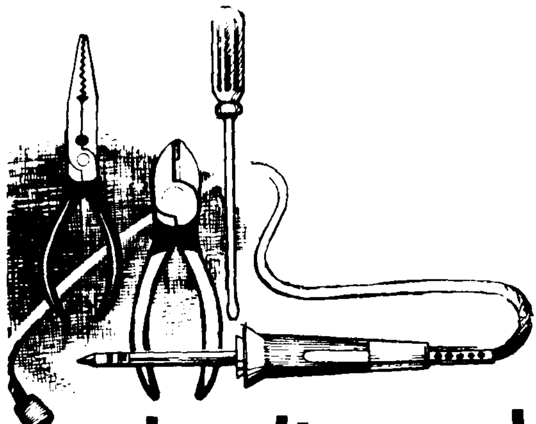
An honest and well-qualified listener, equipped with a conventional a-m receiver with a front end reasonably free of cross-modulation and intermodulation and operated with the agc disabled, af gain high, and the rf gain set to give a moderate signal, can provide meaningful information if he tunes slightly to either side of your signal as you talk normally. Ask the operator to listen for the buckshot effect that results from nonlinear operation of an amplifier. If such distortion shows up only on voice peaks, you're probably overdriving the amplifier. Hold the amplifier excitation low enough to pass the test. Your signal may not kick S meters as high, but you'll have better relations with other amateurs and the FCC.

Linearity is not something that's built into a tube. In addition to the tube characteristics, linearity depends upon external factors such as grid bias, grid excitation, plate voltage, and plate loading. These factors are mutually dependent, so it is not remarkable that true linearity is difficult to approach. Note that you can approach it but never achieve it.

Don't hesitate to juggle grid excitation and plate loading to obtain the best possible signal. Usually the plate loading must be very heavy. As a last resort, try a different value of grid bias remembering that this bias always must come from a source of low internal resistance (strapped-down supply). Also bear in mind that linearity is more nearly approached when the tube bias point is such that the tube's rated plate dissipation is not exceeded.

ham radio

*However, consider the article by Marv Gonsior, W6VFR, in the March, 1972, issue of *ham radio*. Marv shows how ssb signals can be evaluated with a monitor scope connected to a receiver when the receiver bandwidth is appropriately modified to pass essential information. **editor.**



circuits and techniques

ed noll, W3FQJ

emitter-coupled logic

I introduced the basic types of digital IC circuits in an earlier column.[1] One of these types was the emitter-coupled logic (ECL). These are often referred to as MECL types which is a Motorola terminology.[2] There are several categories of MECL types according to speed of operation. The family identifiers are MECL-I, MECL-II, MECL-III and MECL-10,000.

The identifiers have to do mainly with the two electrical characteristics of toggle rate and gate propagation delay. The toggle rate is the frequency with which the logic activity can be made to changeover in one second. For example, if the family has a toggle rate of 30 MHz, a multivibrator of that class could produce 30 million output pulses per second.

A digital circuit requires a certain amount of time to changeover from one logic to another. Consequently there is a certain delay between the time of the *input signal* and the change of logic at the output. Such delay is defined as a propagation delay and is, in effect, a measure of the speed with which a digital IC circuit can be made to function. Propagation delay is usually measured in nanoseconds (a nanosecond is 10^{-9} second).

The MECL families are classified as follows:

MECL-I – 30 MHz toggle rate and 8 nsec propagation delay.

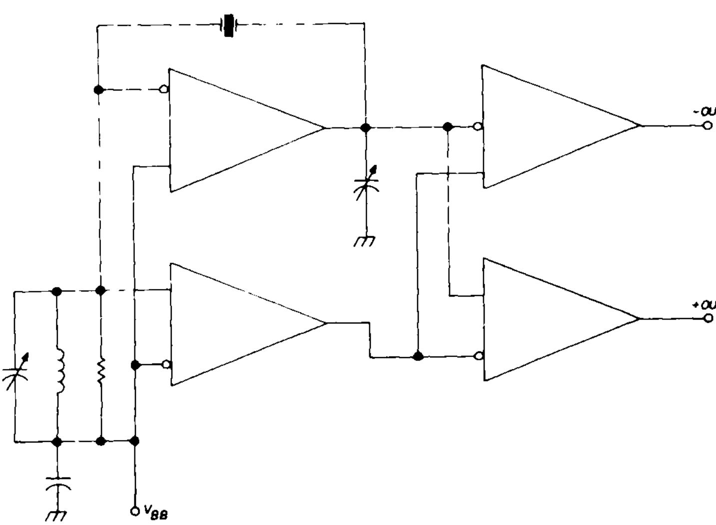


fig. 1. MECL III oscillator using an MC1692.

MECL-II – 70 MHz toggle rate and 4 nsec delay.

MECL-III – toggle rate above 200 MHz and 1 nsec delay.

The MECL 10,000 is a variation of the MECL-III type that fits into large systems and popular circuit wiring methods with greater ease. Propagation delay is 2 nsec associated with an edge speed of 3.5 nsec. Edge speed has to do with the rise and fall times of the pulses. If full benefit is to be derived from high-speed digital circuits, their associated signal input edges must also have a fast time. The maintenance of adequate edges, free of ringing and distortion, imposes strict requirements on interwiring. These requirements are relaxed by the MECL 10,000 designs.

Although the above figures are basic to the various types, it must be pointed out that in each family there are modifications and "improved-upon devices" that are better than the stated figures. For example, MECL-II types are now available with toggle rates of 120 MHz or 180 MHz.

The high-speed ECL types are becom-

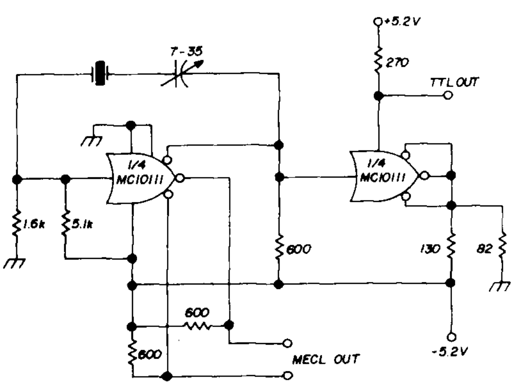


fig. 2. MECL 10,000 oscillator using a MC10111.

ing more prevalent in amateur test gear. Presently they cost more than the popular TTL types but operate at higher frequencies and higher speeds. Often their application as associated with TTL types bear the responsibility for the high speed activities in a given system. In a scaler, for example, an MECL might count down a very high frequency signal to a lower fre-

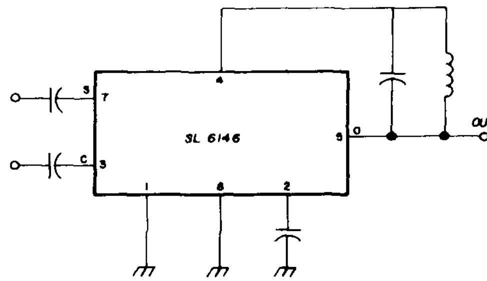


fig. 3. Basic pin-out circuit of a double-balanced modulator using an SL614C.

quency one that can be handled by TTL circuitry. Typical toggle rates for the 7400 TTL series are in the 15- to 30-MHz class. ECL devices are available that can act as a bridge between ECL and TTL types.

high-frequency oscillator circuits

A typical MECL-III crystal oscillator circuit is shown in **fig. 1.** Its toggle rate is so high that it will operate in oscillator circuits beyond the highest practical crystal frequency. Your high-frequency limitation, in this case, is not the device but the crystal itself. Remember that the output is a square wave, and if not lost in the output coupling system, strong harmonics are present in the uhf and low-frequency microwave spectra.

The circuit of **fig. 2** uses an MECL-10,000 type and will operate up into the vhf spectrum. Circuit plan is such that either MECL or TTL outputs are available. The TTL output is such that it can drive a TTL input device or counter. It is said to provide the proper interface between MECL and TTL.

frequency multiplication and division

To some extent the doubly-balanced modulator linear IC has been overlooked by the radio amateur as a means of frequency multiplication and division. An especially mind-jogging article appeared in the January, 1972, issue of *Electronic Equipment News* (British) stressing the fact that these devices can be used in circuit arrangements that provide more than integral multiplication and division.[3] The device type used was the Plessey SL640 and SL641. The SL640 and SL641 can be made to multiply and divide over a frequency range of 100 Hz to 100 MHz. No doubt similar results can be obtained from the RCA CA3050, Signetics and Motorola MC 1596, and other types made in the United States.

The basic circuit of the device, **fig. 3**, shows signal and carrier inputs and a tuned output. The tuned output, of course, minimizes the generation of fundamental and other undesired components. In the usual application of a double balanced modulator there are signal and carrier input signals. In the device these two components cancel but mix and produce either a sum or difference frequency (**fig. 4A**) at the output

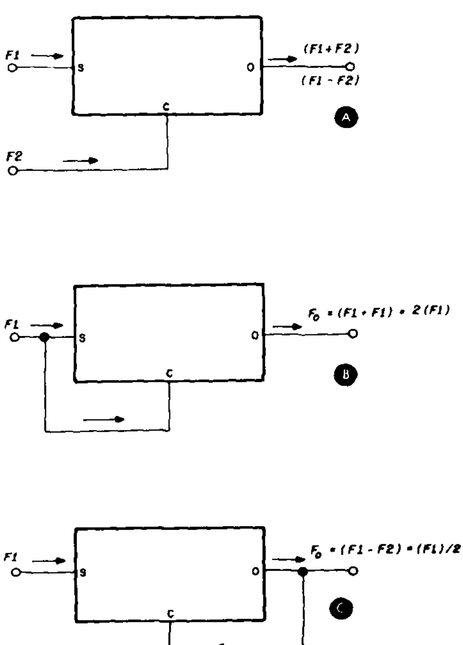


fig. 4. Balanced modulator inputs and outputs. A is the basic circuit, B is the basic doubler and C is the two-to-one divider.

(F1 + F2) or (F1 - F2). When the double balanced modulator is used as a multiplier or divider, only one input signal is necessary, **figs. 4A** and **4B**. Either the input

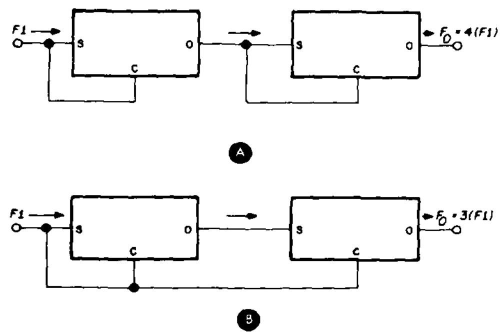


fig. 5. A frequency quadrupler and tripler.

signal is applied to both device inputs or the second input is derived from the output.

The B circuit operates as a doubler; the C circuit, a 2-to-1 divider. The sum component at the output of circuit A is of course (F + F) or 2F. In B circuit the signal input is Fi and the carrier input is Fo. The output is tuned to the difference frequency, therefore:

$$Fo = Fi - Fo$$

$$2Fo \approx Fi$$

$$Fo = Fi/2$$

Two doublers can be connected in cascade to obtain a multiplication of 4, **fig. 5A**. Output of first modulator is 2F or (F + F). Output of the second multiplier is 4F or (2F + 2F).

If the input signal is also made the carrier input signal of the second modulator, the balanced modulator pair operates as a tripler, **fig. 5B**. Output of the first modulator is again 2F while the output of the second modulator is 3F or (2F + F).

A division by four can be obtained by cascading two 2-to-1 dividers, **fig. 6A**. Odd division using balanced modulators requires feedback paths like the odd-divider designs of digital integrated circuits. In the case of the balanced modulator, the desired 1/3 output is removed between stages, **fig. 6B.** Additionally a 2F/3 component is available at the output of the second stage.

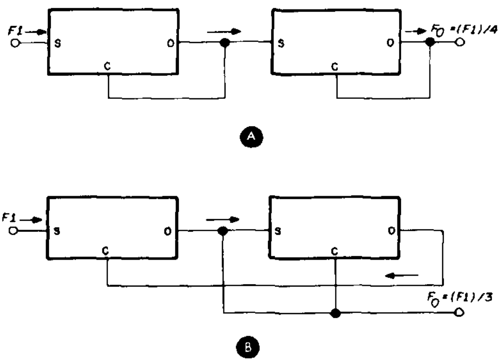


fig. 6. Frequency division by four and by three.

Three, four or five stages can be used to establish various integral and fractional *multiplications and* divisions. One can anticipate the use of both linear and digital multipliers and dividers in various types of amateur gear including transmitters. Much frequency processing and *even modulation can be expected to* occur at the low power levels of these circuits. Pulse waveforms often facilitate processing and it is no great problem to convert square waves to sinusoids. This is demonstrated in an earlier experiment where a 7-MHz crystal was used to generate a 3.5-MHz sine wave using a digital two-to-one divider.[4] I am experimenting with these devices and I hope to bring you some practical circuits before the end of the year.

waveform generation

Additional function generators in the form of monolithic chips are being made available. A very appealing one has been developed by Exar Integrated Systems, Inc. In a recent article by Allan E. Grebene, the unusual versatility of such a device was stressed.[5] This 16-pin in-line device can generate sinusoidal, triangular, square, sawtooth, ramp and pulse waveforms. These various waveforms can be amplitude modulated (double-sideband or suppressed carrier), frequency modulated or a combination a-m and fm modulation. The unit can be used to generate a sweep waveform or a tone-burst signal. Regular CW on-off keying is possible as well as FSK or PSK keying. Groups of these waveforms can be made available simultaneously. Here is a possibility for a transmitter design that also includes the generation of its own test and measurement waveforms as well.

The Exar-205 waveform generator consists of three major sections as shown in **fig. 7**. These are voltage-controlled oscillator, modulator and buffer amplifier. The oscillator makes available linear and ramp waveforms at its output. Frequency range of sine and square-wave generation is 0.1 Hz to 5 MHz. Triangle and ramp waveforms have a range between 0.1 Hz and 500 kHz. The oscillator frequency can be adjusted with a variable d-c voltage applied to pin 13. An audio or other modulating wave applied to the same pin will produce frequency modulation of the oscillator output.

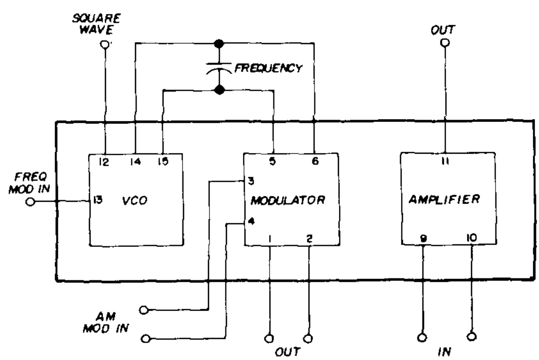


fig. 7. The basic plan for the Exar XR-205 waveform generator.

When a sinusoidal or triangular wave output is desired, the output of the oscillator is applied to the input of the modulator. This wave can be amplitude modulated by applying an appropriate signal to the second input of the modulator. The modulated or unmodulated sine wave or triangular wave can be taken off at the output of the modulator.

A buffer amplifier is also included in the chip. The signal at pins 1, 2, 12 or 14 can be applied to the buffer, and the amplified output can be removed at pin 11.

A practical circuit arrangement is shown in **fig. 8**. Ramp voltage is removed from the oscillator between pins 14 and 15. Capacitor C1 sets the oscillator frequency. Oscillator signal is applied to the modulator by way of pins 5 and 6 with a sine or triangle wave output present across pins 1 and 2. The wave-shape of the output is determined by the setting of the potentiometer connected between pins 7 and 8.

Amplitude modulation results when the appropriate modulating wave is applied to pin 3. Potentiometer R2 sets

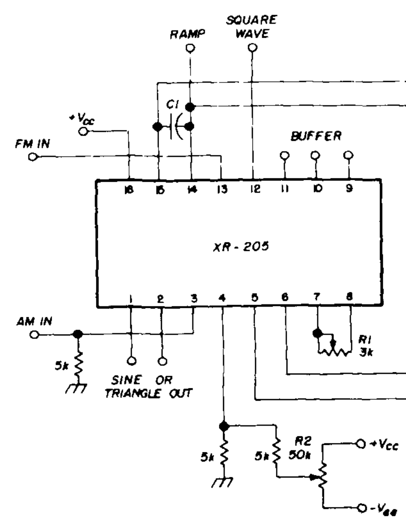


fig. 8. A practical function generator.

the dc bias voltage at pin 4, regulating the magnitude of the output signal.

six meter QRPP

The Siliconix 2N5912 dual-differential amplifiers perform well in push-pull oscillator circuits because of their uniformity. The device will operate as an oscillator to 100 MHz and above. Total device dissipation is about 500 milliwatts and, therefore, it is no great problem to obtain over a 100 milliwatts output on six meters. The circuit of **fig. 9** performs well with the inexpensive EX overtone crystals

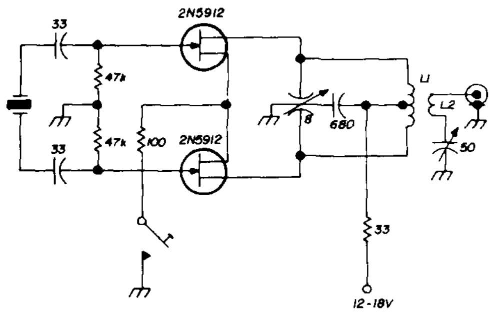


fig. 9. A very low power 50-MHz transmitter.

made available by International Crystal Manufacturing Company. The output capacitor is an 8-pF butterfly connected across a coil made from B&W 3011 stock. The coil is seven turns, center tapped. The output winding is two turns of hook-up wire wound around the center of the primary. It will load the usual 50- to 70-ohm six-meter antenna without the use of an output tuning capacitor. More critical loading to other antenna types can be obtained by adjusting the secondary turns or inserting a series tuning capacitor as shown. The transmitter will operate on other bands with the use of appropriate crystals and balanced output resonant circuits.

references

1. Edward M. Noll, W3FQJ, "Circuits and Techniques," *ham radio*, April, 1972, page 60.
2. William R. Blood, Jr., "MECL System Design Handbook," *Motorola* Semiconductor Products, Inc., Mesa, Arizona.
3. James M. Bryant, "Design Aids for Double Balanced Modulators," *Electronic Equipment News* (British), January, 1972, page 51.
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ham radio

More Details? CHECK—OFF Page 110

the ham notebook

electronic keyer paddle

Having built an electronic keyer, I needed a paddle to operate it. Because of cost, poor feel, or my desire not to sacrifice either my straight key or my bug, I decided to build my own paddle. The final model of my paddle cost me nothing, and although it sacrifices a little adjustability, it fits my requirements well and can easily be enclosed in the same box as a keyer, as the paddle only measurers 1 5/8 x 1 x 1-inch.

Fig. 1 illustrates the keyer paddle and gives enough data to duplicate my unit; however, a few comments may clear up some questions. The rubber band allows a one-shot tension adjustment but, by changing the number of loops or by changing the thickness of the band or by varying its position, you can get any tension you want. I was going to use a non-conducting plastic spring but it was expedient at the time to use a rubber band. It worked so well I left it in. You'll probably have to replace the rubber band every so often but its no trouble and it gives you another chance to admire your handiwork. My first one lasted over a year and the second has been going for longer than two years now. It seems to me that when I was a kid we used glycerine on the model airplace rubber bands to extend their life so you might try that. I used one of those small office rubber bands about one inch long and a sixteenth of an inch thick. I send code practice three times weekly in addition to my normal cw operating, so the paddle gets a generous workout.

I used a 6-32 steel machine screw and four nuts for the shaft and bearings. The philosphy here is to get plenty of bearing surface; so large diameter and fine threads are best. However don't go overboard because you might have trouble with foil separation when soldering large nuts to the circuit board. The nuts are ground on one side to allow clearance. A bench grinder, belt sander or such will work here – even a file.

The slots cut in the brass angle stock determine the paddle throw, so be careful not to make them too large. The paddle throw could be made variable in different ways, but generally once throw is set the way you want it, it never is touched again. If you need adjustment, the machine screw can be set a variable distance from the brass angle.

This keying paddle works fine with either a standard or squeeze keyer. My paddle is housed in a 4 x 4 x 2-inch black crackle utility box together with batteries, keyer, sidetone generator and 3-inch speaker. It was built as a present for my wife, but you know how that is.

Kenneth R. Klopf, KL7EVD

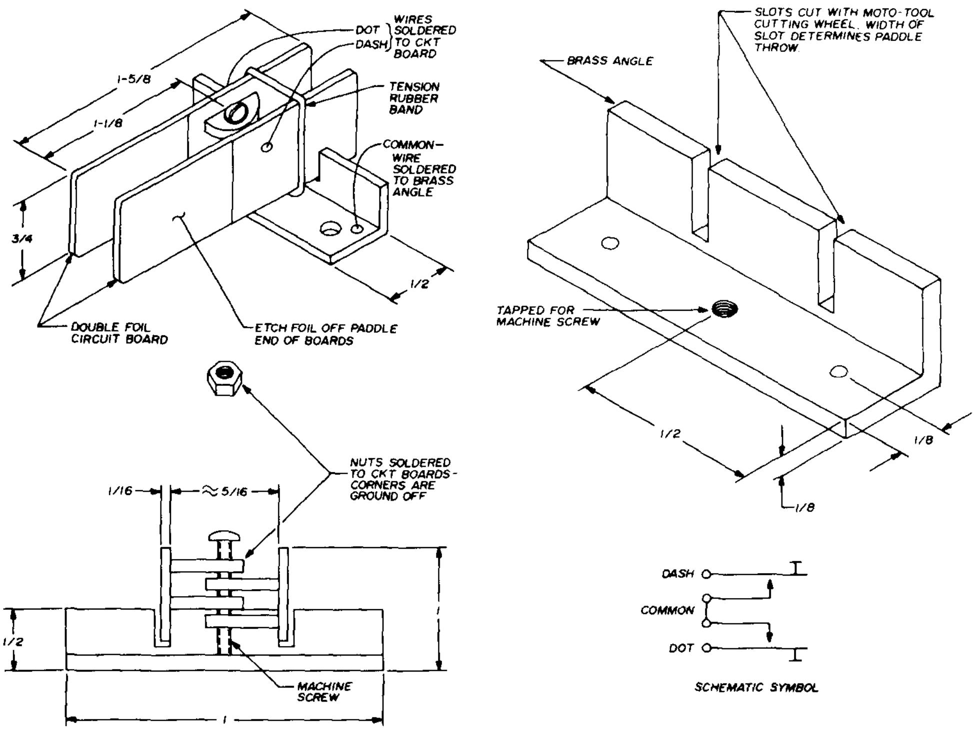

fig. 1. Construction details of the simple keyer paddle.

frequency standard

A stable and highly accurate signal for calibrating counters, meters, or frequency sources can be found in every color television receiver. The local color subcarrier oscillator, at 3.579545 MHz, is crystal controlled and phase locked to the transmitted "color burst" signal from the television station. If the program is of local origin or a delayed tape presentation, this frequency is stable to about one part in 10^8 short term – or one cycle in three seconds. This is more than sufficient for most amateur work and exceeds the capabilities of many inexpensive counters.

If the local station is transmitting a live program from New York such as a national news special, some sports events or some daytime game shows, the color-burst signal will be phase locked to the network rubidium standard and the color TV set's 3.579545 MHz oscillator will be essentially as stable as the standard – typically one part in 10^{12} per day. This resolution is beyond the needs of any but the most advanced or fanatical workers.

Aarne T. Haas, WA7JIK

scanning receiver interference

With the increasing popularity of police-band vhf-fm scanning receivers, a number of amateurs operating on 2-meter fm have had very disconcerting engagements with a new form of interference — *scanning receiver interference*. SRI appears as an interruption of normal scanning reception of the police band by quite clear and intelligible reception of a local 2-meter amateur.

The cause of the interference is quite simple to understand and, like most interference problems, it is caused by the design shortcomings in the receiver circuitry. These scanner receivers utilize a frontend which uses gated conversion local oscillators capable of scanning some 6 to 8 MHz of the vhf-fm public-service band. Obviously, the rf amplifier preceeding the converter stage in such a radio would have to have a broad response. Unfortunately, some of these are a little too broad and are easily overloaded when operated in a high-strength rf field produced by a 2-meter fm transmitter. This overload in the receiver frontend generates products which look like signals to the rest of the receiver, and the receiver stops scanning and presents beautiful, cleanly-detected 2-meter fm audio — generally to the receiver owner's dismay.

The owner's first reaction is usually to find out "who is interfering with the police and fire broadcasts," and inform him of this fact. This can be an unnerving and embarrassing experience for the unknowing amateur. The correct action to take, though, is the same as for a television-interference problem.

First make sure you are clean. Successful operation of a good-quality police-band receiver while your transmitter is in operation should establish this. The owner of the automatic eavesdropper should then be told *politely* that the problem is one of receiver design. He should be requested to write to the manufacturer to explain his problem and request assistance.

Not all scanning receivers are plagued with SRI. The Digi-Scan, manufactured by Unimetrics, appears to be much less susceptible to this problem than some of the more common scanners such as the Bearcat and the Courier. Of course, good-quality, non-scanning receivers with narrow front-ends are the best choice to prevent SRI. (Adapted, with permission, from *The RaRa Rag*, published by the Rochester Amateur Radio Association.)

Joseph Hood, K2YAH

uhf coax connectors

If you dread installing uhf coax connectors because you have a tough time threading the outer jacket of the coax into the connector, try this. Trim the end of the coax in the usual manner per the *ARRL Handbook*. Daub a drop of silicone grease, about the size of a match head, on the black jacket just back of the exposed braid. As the connector is threaded on, it will pick up the silicone grease and turn on like a nut.

Floyd R. Patten, WØLCP

cold galvanizing compound

After designing and building that antenna to end all antennas, the finishing touch should provide long life. *Cold Galvanizing Compound*, manufactured by Crown Industrial Products Company*, can do the job. This spray-can product is light gray in color and easy to apply. It provides a zinc-rich coating which protects metallic materials from rust and corrosion.

The Cold Galvanizing Compound provides protection in two ways. First, as a long-lived coating of practically pure zinc; and second, through galvanic action. This becomes effective when the surface is scratched or broken — with the presence of moisture galvanic action takes place, but the corrosion of the zinc coating will protect the metal it covers.

Hilary McDonald, W5UNF

*Crown Industrial Products Company, Hebron, Illinois 60034.

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new products

ssb and CW transceiver

Hallicrafters introduced a new, low priced, completely self contained ssb and CW transceiver, the FPM-300. It is compactly designed with modular construction techniques for fixed, portable and mobile use for amateur, CD, CAP, MARS, RACES and other utility hf communications services.

The new transceiver provides the user with an extended range vfo (600 kHz) for full-frequency coverage of 80 through 10 meters.

Priced at $595, amateur net, the transceiver features low power drain, conservatively rated 250 W PEP input on ssb and 180 W on CW. The unit is all-American made with American components. It uses glass-epoxy pc boards and over 70 active electronic devices.

Other features of the unit include a large, easy-to-read frequency display which can be interpolated to 1 kHz, combination S/tune meter, built-in vox and semi break-in CW, an IC speech compressor, aalc, 100/50/25-kHz crystal calibrator and a universal power supply for 117/234 Vac, 50/60 Hz and 12 Vdc.

For additional data on the FPM-300, write to the Hallicrafters Company, Amateur Radio-Department PR, 600 Hicks Road, Rolling Meadows, Illinois 60008 or use *check-off* on page 110.

semiconductor lasers

Both Ralph W. Campbell, W4KAE, and Forrest M. Mims have written articles and letters in *ham radio* magazine about laser experimentation. These two men have now come out with a new book on the subject entitled "Semiconductor Diode Lasers." The new book is written in a comprehensive but easy to read style and introduces experimenters and design engineers to the injection laser – one of the most unique and challenging semiconductor devices in electronics today.

The first chapter discusses the history and development of the laser. It explains light-emitting diodes, the injection-laser theory and such lasers as the solid, liquid, gas, plastic, gelatin and space.

Chapters two and three describe the fabrication and the electrical properties of the injection laser. Also explained is coherence, a very significant aspect of laser light.

The remaining chapters deal mainly with circuitry and practical applications. Circuitry encompasses pulse generators, modulators, power supplies, detectors and receivers. Optical systems and viewing devices are also mentioned.

More Details? CHECK–OFF Page 110

More Details? CHECK—OFF Page 110

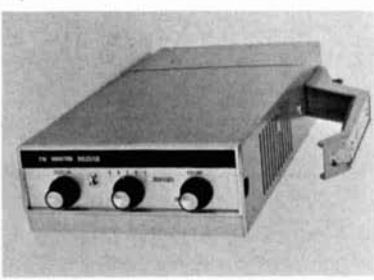
The final chapter covers several of the many applications which are realities and suggests others to come.

This first edition book also contains appendices on laser safety, range equations and addresses of manufacturers. Finally, the book is rounded out by a wide variety of conventional and infrared photographs.

With large-scale, practical light-beam communications still years in the future, this book on laser injection provides valuable research material and is a most interesting book for the experimenter searching for an area in which he can possibly add to man's knowledge.

The book is 192 pages, softbound, and is available for $5.95 from Comtec Books, Greenville, New Hampshire 03048. This new book is published by Howard Sams.

fm monitor receiver



E. F. Johnson has introduced a new non-scanning fm monitor receiver featuring one-at-a-time coverage of five channels. Intended for mobile use in the 150-174 MHz band, the all solid-state unit can be powered directly by a 12-Vdc power source or from an optional ac power supply or field battery pack. The receiver features a dual-conversion circuit with a crystal filter, 5-watts audio output, built-in speaker, true noise-operated squelch, external speaker jack and SO-239 antenna connector. The receiver sells for $119.95.

More information can be obtained from any Johnson dealer, direct from E. F. Johnson, Waseca, Minnesota 56093, or by using *check-off* on page 110.

pulse tone circuit

A miniature thick film hybrid pulse circuit chip is now available from Alpha Electronic Services. The PT-100 pulse chip, when added to an Alpha ST-85 encoder, creates the necessary time delay pulse utilized for pulse or burst tone CTS systems, telemetry, radio controls and selective signalling systems.

The Alpha ST-85J encoder is contained in one thick film chip, the frequency determining network is one thick film chip and the entire unit when combined with the PT-100 chip makes a very small package (7/8" x 1-1/4" x 1/2"). Because of the miniature size, it is especially useful in handheld radio units or mobile units where space is at a premium.

The thick film hybrid technique is especially desirable where exceptional long term reliability is required or where the high failure rate of reeds is a problem.

As a complete pulse tone encoder the ST-85J, PT-100 is available in any frequency from 20 to 3000 Hz. Temperature range is from -40° to $+100^{\circ}$ C. Current requirement is 4 mA at 12.6 volts, but it will perform within a voltage input range of 6 to 24 Vdc.

Application engineering assistance is available. Contact Alpha Electronic Services Inc., 8431 Monroe Avenue, Stanton, California 90680, or use *check-off* on page 110.

transistor tester

The model 85 transistor tester saves considerable time in locating faulty transistors. In-circuit tests can be made by placing the contacts of the tester against the printed-circuit board. A tone is heard if the transistor is a functioning unit. The absence of a tone indicates a shorted or open transistor. The unit comes with an input extender cable for adapting to various lead configurations. The battery-powered unit costs $17.95. More information is available from Production Devices, 7857 Raytheon Road, San Diego, California 92111 or by using *check-off* on page 110.

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LOOK The CRICKET is here — and it has the jump on all the others in its field!

This low cost keyer has more features for your dollar than all others in its price range. Even some in a higher price range! Go ahead — look around — compare the rest! Then buy the BEST — Data Engineering's **new** CRICKET I.

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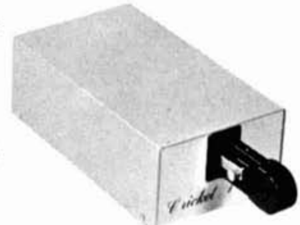

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three-band scanner

A programmable, three-band scanning monitor receiver covering 25 to 50 MHz, 140 to 174 MHz, and 450 to 470 MHz simultaneously, is now available from the Pace Communications division of Pathcom Inc.

The receiver can be programmed easily for monitoring any combination of eight channels in the high band vhf, low band vhf or uhf frequencies. The unit, designated the SCAN 308, holds up to 16 different channels. With simple switch controls the unit can give visual readout for up to eight channels at one time. It was designed to meet the growing need for multiple channel monitoring by amateur and public safety personnel.

Pace's new SCAN 308 has a wide frontend design so that one model, tuned at the factory, can be easily retuned for extreme field conditions. Technical features of the new model include a unique IC and fet transistor complement to provide versatility of broad band adjustments while still maintaining good selectivity and sensitivity. Rear panel programming switches select the desired combination from 16 internal crystal sockets. No internal wiring need be changed. Front panel control lights, with lock out controls indicate which channel is being monitored.

Built for both 12 Vdc mobile operation and 110 Vac home use, the SCAN 308 is provided with ac and dc power cords, a locking mobile mount, non-slip desk mount, telescoping antenna and built-in speaker. There are provisions for external remote speaker as well as external antenna connections. The wood grain styled metal case makes an attractive desk console.

This unique three band simultaneous scanning monitor sells for $189.95. This model is manufactured in the United States and carries a complete two year service warranty on parts and labor.

For more information consult your local Pace registered sales outlet, write directly to PACE, Box 306, Harbor City, California 90710 or use *check-off* on page 110.

fm frequency standard

Data Engineering is offering a ready-built frequency standard designed specifically for the fm enthusiast. The unit puts out markers at 5, 10, 20, 30, 40, 60 and 120 kHz throughout the 10-, 6-, 2- and 1¼-meter bands.

The unit can be easily calibrated against WWV with an adjustment through the front panel. Completely self-contained, the unit is designed for precise frequency output, cancellation of unwanted markers and usable output above 220 MHz.

Calibrated against WWV and with a built in battery holder for four C cells, the unit sells for $44.50 and carries Data Engineering's five year guarantee. For more information write to Data Engineering Inc., Box 1245, Springfield, Virginia 22151 or use *check-off* on page 110.

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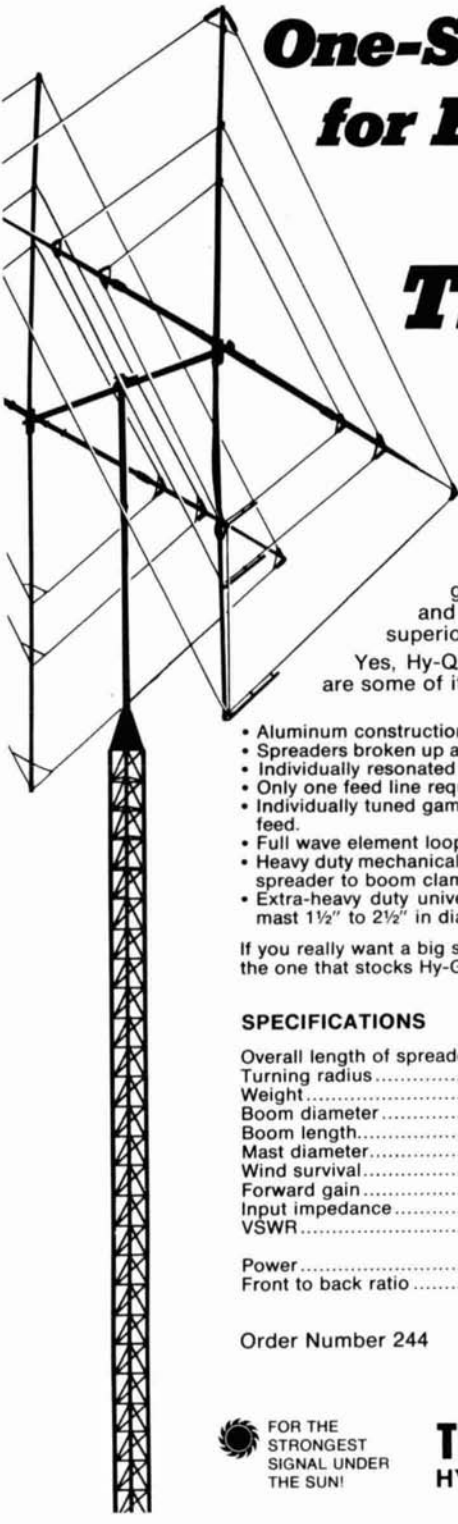

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solid-state electronics

Today, the technician is expected to assume technical responsibilities that formerly were controlled by engineers. As a consequence, the valuable electronics technician, often called an Associate Engineer, must have more than a superficial knowledge of the popular solid-state components now in use. The main objective of "Solid-State Electronics," is to help technicians meet this challenge. George Rutkowski, the author of this new book, not only discusses the fundamentals, but also develops the student's ability to select proper design components for solid-state electronic circuits.

The book begins by explaining common semiconductor materials. Other chapters discuss zener diodes, junction transistors, SCRs, fets and ICs.

A modified programmed style is used throughout the book. Each point discussed is followed by at least one worked example. The student is encouraged to work each sample problem before referring to its solution. The answers to the odd-numbered, end-of-chapter problems are provided at the end of the book. These problems, with the examples, make this book a highly-recommended source for either self-study or classroom use.

"Solid-State Electronics Laboratory Manual" has been written by Jerome E. Olesky to accompany "Solid-State Electronics" to enhance its value as a study course.

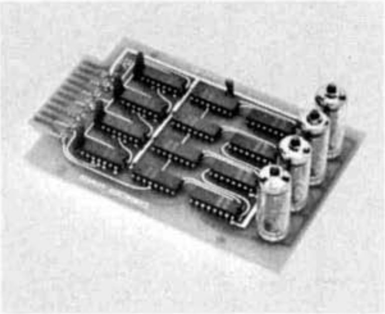
"Solid-State Electronics" is 616 pages, hardbound and costs $15.50. "Solid-State Electronics Laboratory Manual" is 144 pages, softbound and costs $4.50. Both are published by Howard W. Sams and are available from Comtec Books, Greenville, New Hampshire 03048.

theory course

Ameco Publishing Corporation has come out with a profusely illustrated, 448-page course for the first and second class FCC commercial licenses. Broken into 21 lessons, the book is logically arranged so you can study for the second class license and then use the same book to progress towards the first class. The book is quite comprehensive, includes practice tests and deals with over 600 FCC type questions.

The softbound book, catalog number 15-01, is available for $5.95 from Comtec Books, Greenville, New Hampshire 03048.

counter and display modules



A new series of counter and display modules is available from Display Electronics. The CM series modules include a decade counter, latch, decoder-driver and readout for each digit. Standard modules are available with from two to six digits.

All ICs are 7400 series TTL with a typical minimum counting rate of 18 MHz. The modules operate over a temperature range of 0° to 70° C. Lamp test and zero blanking functions are provided. A single 5-Vdc power supply is required for logic and readout. The readout tube is a seven-segment incandescent type with a character nearly one half-inch high. A piece of non-glare polarizing filter material is furnished with each module. Components are assembled on a G10 fiberglass PC board. A rhodium plated edge connector is provided in addition to solder terminals.

The price of a typical four-digit module is $79.00 in single quantity. Custom designed modules are available on special order. Further information is available from Display Electronics, P. O. Box 1044, Littleton, Colorado 80120 or by using *check-off* on page 110.

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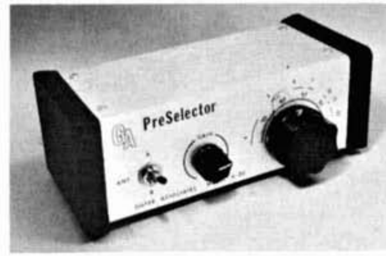
shortwave preselector



The first in a series of specialized products for the forgotten short wave listener has been introduced by Gilfer Associates, Inc. This product is a preselector to enhance weak-signal reception, improve the signal-to-noise ratio in many short wave receivers and virtually eliminate images in single-conversion short wave receivers.

The Model A-20 PreSelector tunes the single range 3.9 to 22.5 MHz. Connected between the receiving antenna and short wave receiver, the A-20 has a noise figure under 2.0 dB and a gain of not less than 18 dB. The gain is variable with a front panel control from near signal cutoff (-40 dB) to the maximum. A slow motion calibrated dial permits setting the A-20 to the peak of its passband (not less than 200-kHz wide at the -3.0 dB points). The A-20 is powered by 117 Vac with transformer isolation for safety. To ensure maximum flexibility, toggle switches are provided for antenna selection and preselector in/out option.

The attractive, compact unit sells for $49.95. More information is available from Gilfer Associates, Inc., Box 239, Park Ridge, New Jersey 07656 or by using *check-off* on page 110.

fm receiver kit

Hamtronics has come out with a new fm receiver kit for the 6 or 2 meter amateur bands or the adjacent commercial frequencies. The kits feature a small size circuit board, low-noise protected mosfet frontend, IC limiter/detector, one-watt audio output stage, narrow-band ceramic ladder filter, posi-

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tive acting noise squelch and built-in test features.

The unit is powered by 13.6 Vdc. An optional adapter turns the standard one-channel unit into a six-channel receiver. The builder supplies his own case, controls and speaker and must drill the board himself. This allows custom installation of the board in home-built transceivers and keeps the cost of the kit down.

The receiver board kit is $54.95. The six-channel adapter is $9.95. Discounts are available to clubs and dealers. More information is available upon receipt of a self-addressed stamped envelope to Hamtronics, Inc., 182 Belmont Road, Rochester, New York 14612 or by using *check-off* on page 110.

transistor substitution handbook

The engineering staff at Howard W. Sams has produced the twelfth edition of their popular "Transistor Substitution Handbook." This latest edition is an up-to-date guide providing the reader with over 100,000 transistor substitutions. To guarantee the most accurate substitutions possible, the electrical and physical parameters as described in the manufacturers' published specifications for each bipolar transistor were fed into a computer; then each transistor was compared with all the others. Consequently, transistors which matched within prescribed limits are listed as substitutes.

Section 1 contains substitutions for both American and foreign transistors which are arranged in numerical and alphabetical order. Types recommended by the manufacturers of general-purpose replacement transistors are included at the end of each list of substitutes. Additional data on these general-purpose replacement types – the manufacturer, the polarity, the material (germanium or silicon) and the recommended applications – are reviewed in Section 2.

This handy and comprehensive book is 176 pages, softbound and sells for $2.25. It is available from Comtec Books, Greenville, New Hampshire 03048.

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Electronic Clock Kit

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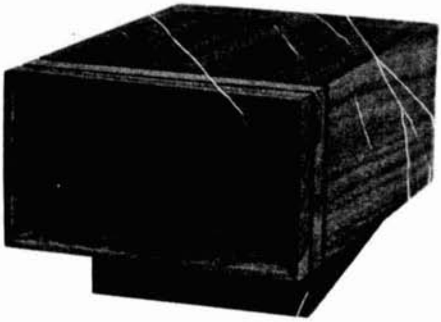

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The BBA-1 series offers high gain over the HF to UHF region with low noise figures. BBA-1PA, a remotely powered unit for mounting near the antenna, covers 30 to 400 MHz with a 20±1dB gain dropping to 17 dB at 500 MHz. Maximum NF is 3.5dB. BBA-1PB has the same specs as the BBA-1PA but is locally powered. BBA-1P covers 3 to 500 MHz. with gain between 15 and 30dB. Maximum NF is 3.0dB. For less critical use order BBA-1 with same coverage as the BBA-1P, but reduced UHF gain and higher NF.

BBA-1PA - $50.00; Adapter Kit, KT-1 - $5.00
BBA-1PB, BBA-1P - $45.00; BBA-1 - $30.00

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No. Crystals	4	8
Center Freq.	9.0 MHz	9.0 MHz
Band Width at 6db	2.5 kHz	2.5 kHz
60db/6db Shape	2.0 (45/6)	1.8 max
Ultimate Rejection	45 db	100 db min.
In/Out Termination	120 Ω	140 Ω
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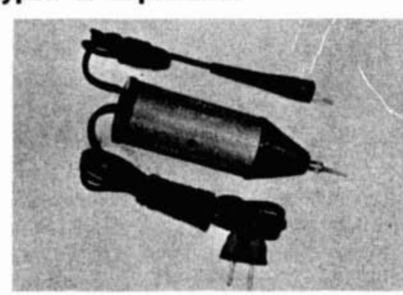

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• **Linear permeability tuned VFO** with 1 kc dial divisions. VFO and crystal frequencies pre-mixed for all-band stability • **Covers ham bands** 80, 40, 20, 15 meters completely and 28.5 to 29.0 Mc of 10 meters with crystals furnished • **Any ten 500 kc ranges between 1.5 and 30 Mc** can be covered with accessory crystals for 160 meters, MARS, etc. (5.0-6.0 Mc not recommended) • **Four bandwidths of selectivity,** 0.4 kc, 1.2 kc, 2.4 kc and 4.8 kc • **Passband tuning** gives sideband selection, without retuning • **Noise blanker that works on CW, SSB, and AM** is built-in • **Notch filter and 25 Kc crystal calibrator** are built-in • **Product detector** for SSB/CW, **diode detector** for AM • **Crystal Lattice Filter** gives superior cross modulation and overload characteristics • **Solid State Permeability Tuned VFO** • 10 tubes, 10 transistors, 17 diodes and 2 integrated circuits • **AVC** for SSB or high-speed break-in CW • **Excellent Overload and Cross Modulation characteristics** • **Dimensions:** 5½"H, 10¾"W, 12¼"D. **Wt.:** 16 lbs.

$475.00

T-4XB TRANSMITTER

• **Covers ham bands** 80, 40, 20, 15 meters completely and 28.5 to 29.0 Mc of 10 meters with crystals furnished; **MARS and other frequencies with accessory crystals, except 2.3-3, 5-6, 10.5-12 Mc.** • **Upper and Lower Sideband** on all frequencies • **Automatic Transmit Receive Switching on CW** (semi break-in) • **Controlled Carrier Modulation for AM** is completely compatible with SSB linear amplifiers • **VOX or PTT** on SSB and AM built-in • **Adjustable Pi-Network Output** • **Two 8-pole Crystal-Lattice Filters** for sideband selection, 2.4 kc bandwidth • **Transmitting AGC** prevents flat topping • **Shaped Grid Block Keying** with side tone output • **200 Watts PEP Input on SSB**— 200 watts input CW • **Meter indicates plate current and relative output** • **Compact size; rugged construction** • **Solid State Permeability Tuned VFO** with 1 kc divisions • **Solid State HF Crystal Oscillator** • **11 Tubes, 3 Transistors and 12 diodes** • **Dimensions:** 5½"H, 10¾"W, 12¼"D. **Wt.:** 14 lbs.

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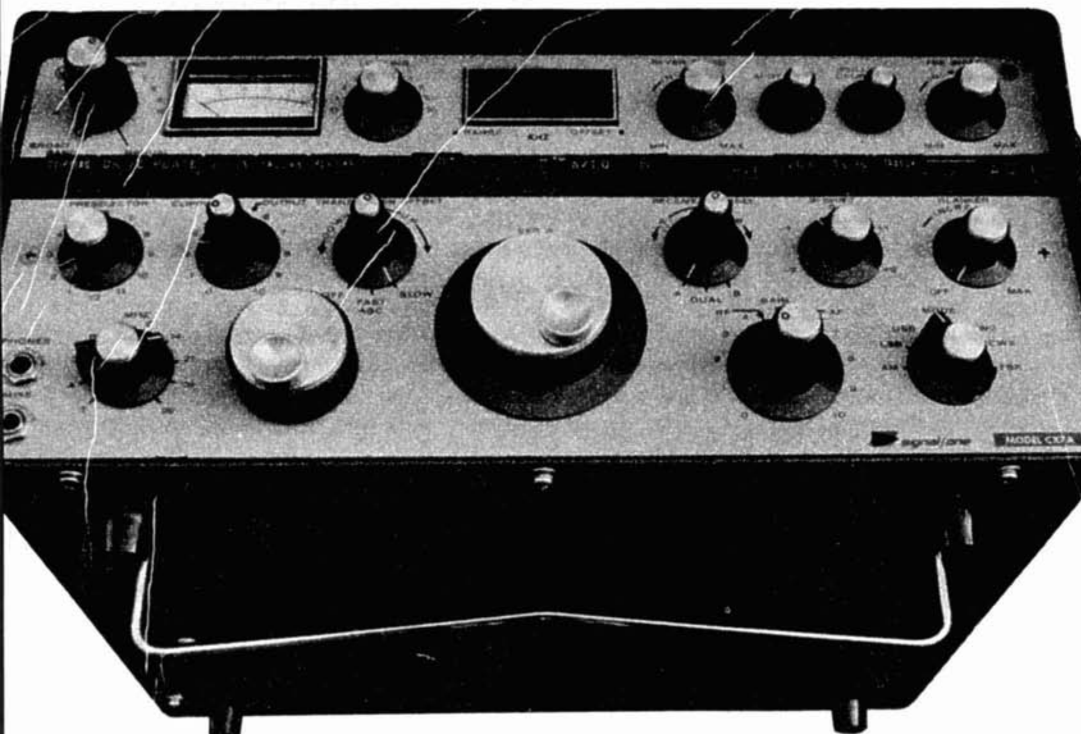
A room full of gear ...right here.



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FM-36 KIT $134.50

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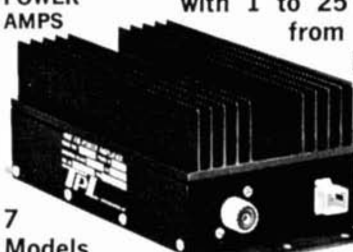

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1 27/64″ x 1 3/64″ x 3/4″

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XF9-A	2.5 kHz	SSB TX	$25.40
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XF9-M	0.5 kHz	CW	$27.30
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XF900	9000.0 kHz	Carrier	$3.05
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F-05	Hc25/u Socket		.50

VHF CONVERTERS UHF

	MM 50	MM 144	MM 220	MM 432	MM 1296
RF Freq. (MHz) †	50-52	144-146	220-222	432-434	
N.F. (typical)	2.5dB	2.8dB	3.4dB	3.8dB	COMING
Nom. Gain	30dB	30dB	30dB	30dB	SOON
	$49.95	$49.95	$54.95	$59.95	

Standard I.F. 28-30MHz †
Power 12v DC
1¼″ x 2⅜″ x 4⅜″ + connectors.
† Other ranges available on request

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SURPLUS & *Parts & equipment for sale.* Filter chokes, power transformers, selenium rectifiers, filter capacitators, variable capacitors, tubes, BC-604, ARC-3, GO-9 transmitters. Wanted Heath IG-82 Sine-Square Wave Generator. Archie Shetler, 159 Elkin Ave., Indiana, Pa. 15701.

RTTY PICTURE TAPES. Stamp for list. John Sheetz, 5 Hansell, New Providence, NJ 07974.

F.C.C. TYPE EXAMS GUARANTEED to prepare you for the F.C.C. 3rd., ($7.00), 2nd. ($12.00), and 1st ($16.00), phone Exams; complete package, $25.00. Research Company, Dept. D. Rt. 2, Box 448, Calera, Alabama 35040

THE MINUTE MAN FM REPEATER ASSOCIATION will host an fm get-together on September 24th at Hal Chamberland"s Farm, W1PFX, in New Braintree, Mass. More information is available from Joe Shenette, c/o Minute Man Repeater Association, Box 381, Hudson, Mass. 01749. Planning flea market, tech assistance, freq. counters, xmtr hunt, family-style picnic, bring your own.

SURPLUS MILITARY RADIOS, Electronics, Radar Parts, tons of material for the ham, free catalogue available. Sabre Industries, 1370 Sargent Avenue, Winnipeg 21, Manitoba, Canada.

PRINTED CIRCUIT DRILL BITS. Trumbull, 833 Balra Drive, El Cerrito, California 94530.

EXPERIMENTERS — *Make etched dual-in-line printed circuit patterns on your board at home.* Quick! Easy! Inexpensive! No taping! Details: Stamp-a-circuit, Box 113H, Westchester, Ohio 45069.

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TONE ENCODERS AND DECODERS — New line of solid state encoders and decoders compatible with any sub-audible continuous tone system. Small in size, usable from 67-250 Hz, $8.95 to $14.95. Send for literature. Communications Specialists, Box 153, Brea, Calif. 92621.

CANADIANS interested in RTTY. We have the ST5 & ST6 RTTY converters in stock either wired or in kit form. Canadian parts and material used where applicable SASE for more information to J. A. Mills Box 851, Stn. A, Scarboro, Ontario.

MORSAVERTER READS HAND-SENT MORSE CODE 10-80 w.p.m. without adjustment, translates c.w. to Teletype code including LTRS, FIGS, CR, LF. Computer circuit uses 63 IC's on one 8 x 10 inch board. Kit of four read-only memories, circuit board, 55-page technical manual $185. Write for details. Petit Logic Systems, 908 Washington, Wenatchee, Wa. 98801.

TONE BURST . . . Inoue Regency owners, now available, 4 frequency, internally mounted tone burst oscillator . . . $29.50. NHE Communications, 15112 S.E. 4th, Bellevue, Wash. 98006. Phone 206 747-8421.

TV & RADIO TUBES 36¢. FREE CATALOG. Cornell, 4219 N. University, San Diego, California 92105.

RESISTORS: Carbon Composition brand new. All standard values stocked. ½ watt 10% 50/$1.00; ¼ watt 10% 40/$1.00. 10 resistors per value please. Minimum order $5.00. Post paid. Pace Electronic Products, Box 161-H, Ontario Center, New York 14520

DIGITAL FREQUENCY COUNTER. *Monitor your received and transmitted frequency to the nearest hertz on 6 nixies.* Will work on almost any rig. For further information write: Northwest Custom Electronics; P.O. Box 22413; Milwaukie, Oregon, 97222.

2 METER FM, Brand New, Inoue IC-20, 1&10 watts, 12 channels, w/mike, cable, mobile mount $259.50, Bob Brunkow, 15112 S.E. 44th, Bellevue, Wash. 98006. Phone 206-747-8421.

WE BUY ELECTRON TUBES, diodes, transistors, integrated circuits, semiconductors. ASTRAL ELECTRONICS, 150 Miller Street, Elizabeth, N. J. 07207. (201) 354-2420.

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CAPTAIN CRUNCH 2600 c.p.s. telephone long distance disconnect frequency whistles (4). Rare. Each $10. Garton; 1301 W. Estes, Chicago 60626.

COPY MORSE CODE automatically, (Ham Radio November 1971) detailed construction plans $14.95. VMG Electronics, 2138 West Sunnyside, Phoenix, Arizona 85029.

WANTED: tubes, transistors, equipment what have you? Bernard Goldstein, W2MNP, Box 257, Canal Station, New York, N. Y. 10013.

WORLD QSL — See ad page 106.

DX'ERS — Dig then out of the Mud. New low noise Dual Gate Mosfet Preamplifier. Nominal 20 db gain. 10-30 MHz. Complete in cabinet. $29.96. Dynacomm, 1183 Wall Street, Webster, N.Y. 14580.

QSL'S — BROWNIE W3CJI — 3111B Lehigh, Allentown, Pa. 18103. Samples 10¢. Cut catalogue 25¢.

4-LAND QSO PARTY, Sept. 9th 1800Z, Sept. 11th 0200Z, logs to fourth district ara, R7, Box 187, Greenville, N. C. 27834.

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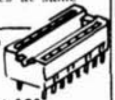

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Uses single Texas Instrument "Chip"
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☐ SN7410	.25
☐ SN7411	.27
☐ SN7413	.55
☐ SN7416	.49
☐ SN7417	.49
☐ SN7420	.25
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☐ SN7438	.53
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☐ SN7443	1.21
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☐ SN7473	.45
☐ SN7474	.45
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☐ SN7476	.49
☐ SN7480	.72
☐ SN7481	1.50
☐ SN7482	.99
☐ SN7483	1.49
☐ SN7486	.55
☐ SN7490	.76
☐ SN7491	1.35
☐ SN7492	.76
☐ SN7493	.76
☐ SN7494	1.09
☐ SN7495	1.09
☐ SN7496	1.09
☐ SN74100	1.44
☐ SN74107	.49
☐ SN74121	.50
☐ SN74122	.67
☐ SN74123	1.06
☐ SN74141	1.55
☐ SN74145	1.33
☐ SN74150	1.55
☐ SN74151	1.13
☐ SN74153	1.55
☐ SN74154	2.30
☐ SN74155	1.39
☐ SN74156	1.39
☐ SN74157	1.48
☐ SN74158	1.48
☐ SN74160	1.79
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Type	Description	
☐ 531	Hi slew rate op-amp	3.58
☐ 533	Micro power 709	3.58
☐ 536	FET input op amp	4.50
☐ 540	70W pwr driver amp	2.04
☐ 550	Precision 723 voltage reg.	1.17
☐ 555	Timer 2 μSeconds to 1 hour	1.19
☐ 560	Phase lock loops (A)	3.25
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☐ 703C	RF-IF, amp, 14 ckts, TO-5	1.00
☐ 709C	Operational amp (A)	.39
☐ 710C	Differential amp (A)	.39
☐ 711C	Dual diff. comp (A)	.39
☐ 723C	Voltage regulator (A)	.95
☐ 741C	Frequency compensator 709	.41
☐ 747C	Dual 741C, TO-5	1.00
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☐ 709-709	Dual 709C (DIP)	1.00
☐ 739-739	Dual stereo preamp	1.98
☐ 741-741	Dual 741C (mini DIP)	1.00
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By RCA or equal 2N3632. NPN, 23 watts, 3 amps, TO-60 case, with stud mtg. VCEV max 65.

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Flourescent Blue-Green — 0-9 numerals, decimals and letters.

	H. x W.	Characters	Filament V.	
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- ☐ 2 — "LEDS", infrared, jumbo, TO-18 ...... $1
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For Class AB use. Basic includes: Signetic 540 30 transistor high power driver TO-5 "IC", with a pair of complimentary 35-watt plastic transistors, i.e. 2N5296 npn and 2N6109 pnp. With schematics, printed circuit and parts board layouts.

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POLY PAKS

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More Details? CHECK—OFF Page 110

"DON AND BOB" GUARANTEED BUYS: SBE144 (249.00 List) 209.95; SBE450 (399.95 L) 339.00; Gladding 25 212.50, with AC 255.00; Standard SR826M 299.95; Motorola HEP170 epoxy diode 2.5A/1000PIV 39¢; Ham-M 99.00; TR44 59.95; Belden 8448 rotor cable 10¢/ft.; Mosley CL33 124.00; CL36 149.00; Hygain TH6DXX 139.00; Hyquad 99.00; 400 rotor 148.00; 204BA 129.00; Airdux 2408T coil 5.00; Belden 8237RG8 15¢/ft.; 8214RG8 foam 16¢/ft.; Collins 75A4 345.00; SX115 250.00; Triex MW50 229.00; MW65 305.00; Cetron 572B/T160L 13.95; KY65 code id 5.95; Sangamo 600MFD/450V 4.95; Mot MC1709CG Op Amp 50¢; write quote note. Prices collect. Mastercharge, BAC. full warranty. Madison Electronics, 1508 McKinney Houston, Texas 77002. 713-224-2668.

FILTERS — Panasonic Ceramic ladder type 455 kHz, bandwidth 15 kHz @ 6 db. $5.00 each. Post paid. Pace Electronic Products, Box 161, Ontario Center, New York 14520.

LINEAR BUILDERS — Motorola HEP170 diodes 2.5A/1000PIV 30¢ each; Plate Choke 90uh., 5KV/2A $6.45; Shielded 30A Dual Filament Choke $6.95; 12,000PIV/2.5A Diode board with RC transient suppressors $9.95; Diode board unfilled $2.50. All Postpaid. K.E. Electronics, Box 1279, Tustin, Cal. 92680.

WANTED — M15 and M32 TELEPRINTERS in any quantity in good condition for use by deaf people . . . will accept donations or for fair prices . . . can be picked up anywhere . . . write Lee Brody, New York-New Jersey Phone-TTY for the Deaf, 15-06 Radburn Rd., Fair Lawn, New Jersey 07410 or call 201-796-5414 evenings.

CHAUTAUQUA COUNTY FM Repeater Association. Announcement of an auction on Oct. 15, 1972, at 11:00 a.m. Shore Acres Boat Yard, Bemis Point, N. Y. 14712.

HEATH SB-310 receiver, perfect unmarred condition, expertly built in 1970. Nine bands including 80-15 meter amateur plus 49-16 meter shortwave. AM, CW, and deluxe SSB filters, 15 meter conversion, calibrator. Price new was $351 (kit). Asking $320. W. Shockley, 17 Hyacinth Drive, Fords, New Jersey 08863.

FOR SALE: SB-610 monitor scope — $90.00 or swap for a "mint" Comm. III — 2 meters. Jim Gysan, W1VYB, 53 Lothrop Street, Beverly, Mass. 01915.

FIGHT TVI with the RSO Low Pass Filter — p115 March 73 — write for brochure — Taylor Communications Manufacturing Company, Box 126, Agincourt, Ontario, Canada.

DISCOUNTS! Standard, Sonar, Clegg, Robyn, Mosley, Cush Craft, Others. Also Marine Gear. Write stating needs. Arena Communications, Dept. H, 1169 N. Military Hwy., Norfolk, Va. 23502.

WRL HAS GALAXY, Drake, Tempo, Hy-Gain, Mosley, Cush-Craft and most other leading new gear. BankAmericard and MasterCharge terms available. Free 72 catalog. World Radio, Box 919, Council Bluffs, Iowa 51501.

GOLDEN JUBILEE HAMFEST beginning Sept. 15 at Silver Slipper Saloon, Klondike Days Exhibition. Full details Box 5986, Station L, Edmonton, Alberta, Canada.

LOW OVERHEAD = LOW PRICES. Most popular two meter rigs. Send for quote sheet. L. M. Communications, 516 Chapman Pkwy., Hamburg, N. Y. 14075.

TECH MANUALS for Gov't surplus gear, only $6.50 each: R-388/URR, R-389/URR, R-390/URR, CV-591A/URR, TT-63A/FGC, TS-403/U, URM-25D. Hundreds more. Send 50¢ (coin) for 20-page list. W31-HD, 4905 Roanne Drive, Washington, D. C. 20021.

THE EIGHTEENTH (18th) ANNUAL V. H. F. CONFERENCE at Western Michigan University, Kalamazoo, Michigan, will be held October 21, 1972 (Saturday). Flea market, speaker from Amsat, etc. For full details write: V. H. F. Conference, Post Office Box 934, Battle Creek, Michigan 49016.

COMPUTER KEYBOARD W/ENCODER $35

Another shipment just received. Alpha-numerics keyboard excellent condition. Once again we expect an early sellout. Price of $35 includes prepaid shipment in the US and shipment made within 24 hours of receipt of order.

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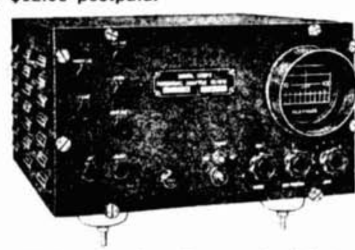
Another fantastic bargain for the builder. We have brand new bounce-less micro switch keys, spares from the above units, less key-tops. Make up your own keyboards. Made for PC mount. Package of 48 brand new key-switches only $12.00 postpaid.



We still have a few Panoramic Adapters BC 1031 excellent condition, "IF" 450-470 Kc, operate from standard 115 volt 60 cycle. $45 each complete with schematic, FOB Lynn, Mass. (60 lbs.)

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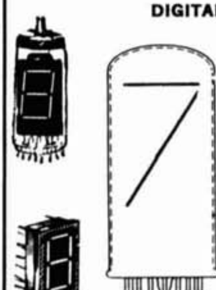

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SMALL SIGNAL DIODES New assorted 30 — 1.00; 75 — 2.00; 200 — 5.00; 500 — 10. B. C. Cond. 3 — 1.00. Electronics Unlimited 204 West St., West Warwick, R.I.

FOR SALE: KWM-2A, 516 — 2, 312 B-5, MP-1, 351D-2, SM-3, MM-2, excl. cond., All manuals $1,200.00 Henry 4K-2 needs new final $350.00, Contact: Richard Dean 215 McArthur Dr., Rt.1, Jacksonville, N.C. 28540. Call 919-324-4379.

CINCY STAG HAMFEST: The 35th Annual STAG Hamfest will be held on Sunday, September 24, 1972 at the ALL NEW Stricker's Grove, on State Route 128; one mile west of Ross (Venice), Ohio Check local area map for new location. Door prizes each hour, raffle, lots of food, flea market, model aircraft flying, and contests. Identify Mr. Hamfest and win prize. $5.00 cost covers everything. For further info. contact: John Bruning, W8DSR, 6307 Fairhurst Avenue, Cincinnati, Ohio 45213.

SAVE MONEY on parts and transmitting-receiving tubes. Foreign-Domestic. Send 25¢ for giant catalog. Refunded first order. United Radio Company, 56-HR Ferry Street, Newark, N.J. 07105.

SURPLUS 7289 (3CX100A5) ceramic sub for 2C39A. Tested 449 Mc. Guaranteed ICAS. $3 ea., $30 doz., plus postage. Only few left. J. E. Howell, W4SOD, Folly Beach, S.C. 29439.

$3,000.00 in FREE PRIZES! On October 7 & 8, 1972, SWAN ELECTRONICS will host its second Annual Open House. Enjoy refreshments, plant tours, technical talks, movies, etc. Free prize drawings for licensed amateur radio operators . . . also, ladies and kids. Located next to Oceanside Airport, overnight trailer and camper facilities will be available. Join the "Talk-In" on 7260 kHz and 146.94 MHz. *Don't miss this family affair — include this visit to* SWAN in your vacation plans. Any questions? Call: (714) 757-7525. SWAN ELECTRONICS — 305 Airport Road, Oceanside, California 92054.

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

NEW ELECTRONIC PARTS. Buy-Sell. Free Flyer. Large catalog $1.00 deposit. Bigelow Electronics, Dept. HR, Bluffton, Ohio 45817.

RECIPROCATING DETECTOR PARTS KIT. Write Peter Meacham Associates, 19 Loretta Road, Waltham, Mass. 02154.

ENCODERS 2805 Hz. or other single frequency. 9VDC, high output, rock stable. 1¾" x 1¾" x ¾". $5.00 postpaid. Richard Puckett, WB4SWW, 707 Setliff Place, Nashville, Tennessee 37206.

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WANTED: R220 in excellent condition. John Raymond, Superior Plating Co., 2500 Post Road, Fairfield, Connecticut 06430.

AMATEUR SALES & SERVICE. Start with discount prices and get service after the sale. We stock such leading names as Clegg, Drake, Kenwood, Regency, SBE, Signal/One, Tempo One. Antennas by Cush Craft and Mosley. Towers by Rohn. Write or call today Amateur Sales and Service, 111 Rand Mill Road, Garner, North Carolina 27529, Tel. 1-919-772-6044.

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MODEL ACA-1 AUDIO COMPRESSOR features 45 DB compression range ■ Flat 20-20,000 Hz response ■ Extremely low distortion ■ Front panel compression meter and in/out switch ■ Accepts both high and low-impedance mikes ■ Easily installed in mike line ■ 110-volt a.c. or 12-volt d.c. operation ■ Only 5" W x 2¼" H x 4½" D.

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(5, 10, and 15 MHz)

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0.25 microvolt sensitivity ■ Crystal controlled ■ 110-volt a.c. or 12-volt d.c. operation ■ Compact size only 4½" W x 2½" H x 5½" D.

Send check or money order, plus $1.50 for shipping anywhere in U.S.A. California residents add 5% sales tax.

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More Details? CHECK—OFF Page 110

NEW MEXICO HAMVENTION on September 15, 16, & 17th. Technical sessions. Other sessions will include traffic, QCWA, ARPSC/AREC/RACES, FCC seminar, joint Air Force, Navy and Army Mars, and an ARRL forum. Saturday afternoon there will be a fashion show and luncheon for the ladies. Displays. Sunday swap fest and ladies may have a swap fest of their own, bringing all sorts of knick knacks. Talk-in frequencies on 146.34/146.94 MHz, 146.16/146.76 MHz, 7.255 MHz, and 3.940 MHz. The affair will be held at the Albuquerque Hilton Inn at the intersection of Interstates I-25 and I-40. Advance registration is $8.50 and registration at the door will be $12.00 For more information, contact The New Mexico Hamvention, P. O. Box 14381, Albuquerque, New Mexico 87111.

SSTV, RTTY, CW, WWV, CHU tone to logic decoder projects. Chassis, plans, hardware, eight 2″ x 3″ epoxy cards, $6. Hornung, 1630 Bowling Lane, San Jose, Calif. 95118.

$3,000.00 in FREE PRIZES! On October 7 & 8, 1972, SWAN ELECTRONICS will host its second Annual Open House. Enjoy refreshments, plant tours, technical talks, movies, etc. Free prize drawings for licensed amateur radio operators . . . also, ladies and kids. Located next to Oceanside Airport, overnight trailer and camper facilities will be available. Join the "Talk-In" on 7260 kHz and 146.94 MHz. Don't miss this family affair — include this visit to SWAN in your vacation plans. Any questions? Call: (714) 757-7525. SWAN ELECTRONICS — 305 Airport Road, Oceanside, California 92054.

HEATH DX-100 transmitter, operating condition, built in 1960. Manual included. Perfect for novice or CW operator. $80 or best offer. W. Shockley, 17 Hyacinth Drive, Fords, New Jersey 08863.

PHILADELPHIA, PA. First annual Pack Rat Hamarama, Sunday October 1, 1972, at the Warwick Fire Co., Jamison, Pa., located on Rt. 263 above Willow Grove, Pa. Activities include giant flea market, auction, and an amateur TV demonstration by the leading local ATV'ers. Festivities begin at 10 A.M. Food concession on premises. Registration is $1.00, flea market tables or tailgate sales, $2.00. Talk-in on 146.94 and 52.525. For further information contact W3ZD at 520 Centennial Rd., Warminster, Pa. 18974.

NOSTALGIA. A handsome series of books to bring back yesteryear. Reprints of old Sears, Montgomery Ward & Marshall Field catalogs. Books on old time autos, toys, and ladies fashions. Write today for full details. Comtec, Greenville, NH 03048.

F. C. C. TYPE exams guaranteed to prepare you for F. C. C. 3rd. ($7.00), 2nd. ($12.00), and 1st. ($16.00) phone exams; complete package, $25.00. Research Company, Rt. 2, Box 448, Calera, Alabama 35040.

HAMFEST IN MEMPHIS, September 17, State Technical Institute, Interstate 40, east of city. Prizes, flea market, tech talks, MARS meeting, XYL activities, food. 8:00 a.m. to 5:00 p.m. Talk-in on 2M .34-.94, .22-.76, 75M, 3.980. Write Evin, WB4VDH, 239 Kenilworth, Memphis, Tennessee 38112.

BE SURE to take advantage of Ham Radio's Summer Sale. Details were sent to you, but if you want another copy of this offer write: Summer Sale, Ham Radio, Greenville, NH 03048.

SJRA HAMFEST on Sunday, Sept. 10, 1972, at Molia Farm, Malaga, N. J., **rain or shine.** Greatly expanded Swap Shop. Protected pavilion containing tables for Swap Shop and special parking will be provided at the Hamfest for hundreds of cars for those who prefer to display in the trunks of their cars. A variety of contests, games, and displays, plus prizes. Picnic and protected swimming facilities will also be provided to help make a gala event for the entire family. Advance registration at $2.00 per family ($3.00 at the gate). Write Fred Holler, W2EKB, 348 Bortons Mill Rd., Cherry Hill, N. J. 08034. Molia Farm is located just off Route 47 at Malaga Lake, Malaga, N. J.

YOUR AD belongs here too. Commercial ads 25¢ per word. Non-commercial ads 10¢ per word. Commercial advertisers write for special discounts for standing ads not changed each month.

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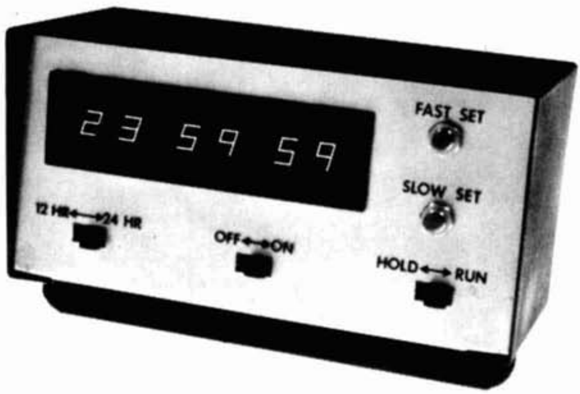
12-24 HR DIGITAL CLOCK



- LED Display
- 12-24 Hr Switch Selectable
- Easily Set
- Compact Size

The Model 8800 Digital Clock has versatility unmatched by similar units at more than twice the price. Ideal for electronics enthusiasts, hams, radio and television studios and event timing. Solid State LED displays end display replacement problems. Foolproof presetting controls combined in a conservative reliable design assure long term accuracy. The 8800 may be used with its own internal time standard or external standards can be used. BCD outputs are available. The unit is shipped fully assembled and calibrated.

8800 Digital Clock $94.95

KEYBOARDS

At last! A low cost keyboard with touch-tone coding built into the switches. Great for repeater and relay applications. The KB-3 will interface directly with all popular logic types and can program the 566 VOC for the standard frequencies. The KB-3 measures 3" x 2½" and has a total depth of ½". Keyboard legends will not chip or wear off. Contacts rated at 25 V and 40 mA. Bought straight from the manufacturer.

KB-3 Touch-Tone Keyboard $7.95

Get your 48-page, 1972 catalog immediately! Send 30¢ for First Class, 40¢ for Air Mail delivery.

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1. 0.5 TO 30 MHz CONTINUOUS COVERAGE - DIRECT READOUT
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Power Amplifier Of The Seventies

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If you want to move up to the BEST, give DON PAYNE, K4ID, a call for personalized service, a brochure, and a KING-SIZE trade-in on any gear you have — one piece — or the whole station.

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- No modification or rewiring on your Communicator. Just plug into mike jack and crystal socket.
- Compact self-contained modulator measures 4" x 3" x 1½".
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- FM at a tenth the cost of a new rig.
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September 1972

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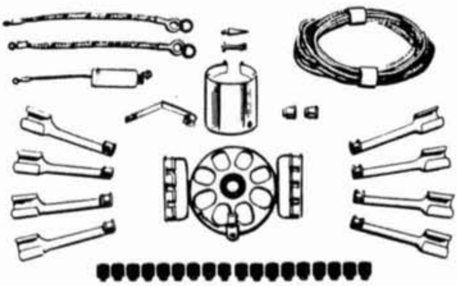

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LIMITED

SPECIAL $24.95

$55.00 VALUE

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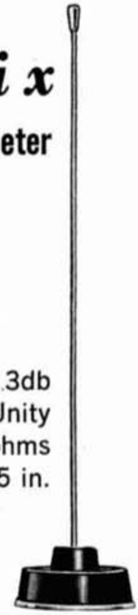

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Gain (2 Meters) 3db
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Nominal Impedance 55 ohms
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$285.00	T4X	T4XB	$495.00
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STOP THAT T. V. I.

3-30 MEG. W/80 DB/AT 42 MEG.

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SSB TRANSCEIVER

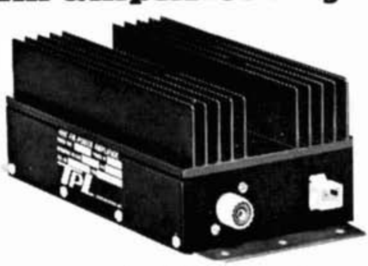
. . . . represents the culminating achievement of many years of experience in the amateur radio field. Modern design, superb performance, high styling, sturdy construction, outstanding reliability, exceptional value .

Tempo "ONE" Transceiver	$319.00
AC/ONE Power Supply (117/230 Volt 50/60 cycle	$ 99.00
DC/1-A Power supply (12 volts DC)	$110.00

TEMPO/fma

the top of the Tempo VHF line. This transceiver offers all of the famous Tempo quality and performance at 25 watts of power output. The unit also features a low power position for 10 watts output to conserve battery power. Here is a true value in VHF FM; Tempo presents high power operation for only $349.00.

powerful performers ... reasonably priced ... high power fm amplifiers by Tempo



TPL502

A superior quality VHF FM two meter power amplifier. Only 6½" x 3½" x 3", yet contains all the features of the TPL 1002-3 and provides a minimum of 45W output and typically 50W. Price $99.00

THE MOST COMPLETE LINE OF SOLID STATE AMPLIFIERS AVAILABLE

MODEL NUMBER	POWER INPUT	POWER OUTPUT (min)	BAND	PRICE
TPL1002-3	5 to 25W	100-135W	2M	$220.00
TPL1002-3B	1-3W	80W	2M	$235.00
TPL802	5W	80W	2M	$180.00
TPL802B	1 to 3W	80W	2M	$195.00
TPL502	5 to 15W	35-55W	2M	$105.00
TPL502B	1 to 3W	45W	2M	$130.00
TPL252-A2	1W	25W	2M	$ 85.00
TPL445-10	1 to 2.5W	12W	440MHz	$125 00
TPL445-30	4W	30W	440MHz	$215.00
TPL445-30B	1W	30W	440MHz	$235.00

TEMPO FMP

Truly mobile, the Tempo fmp-3 watt portable gives amateurs 3 watts, or a battery saving ½ watt, FM talk power anyplace at anytime. With a leather carrying case included, this little transceiver will operate in the field, in a car, or at home with an accessory AC power supply. The battery pack is of course included. Price:$225.00.

Other Tempo products:

FMV450 - 10 watt UHF transceiver
FMV - 10 watt 2 meter transceiver
RBF-1 Wattmeter & SWR Bridge
VHF & UHF Solid State Amplifiers

Henry Radio

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