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ham radio magazine

APRIL, 1971

this month

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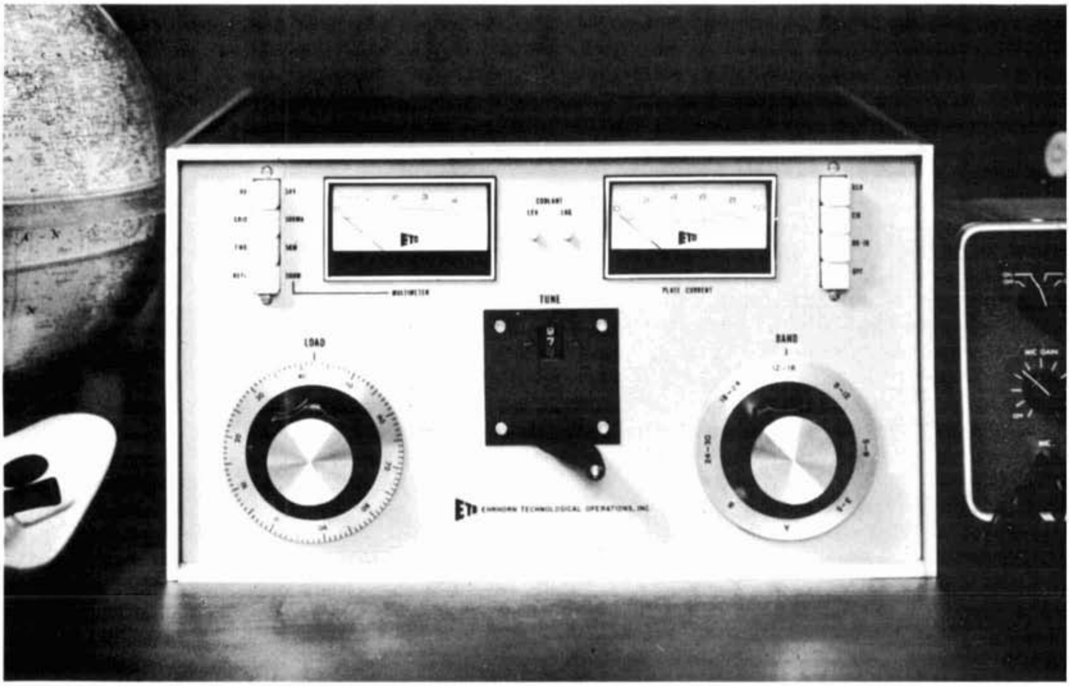

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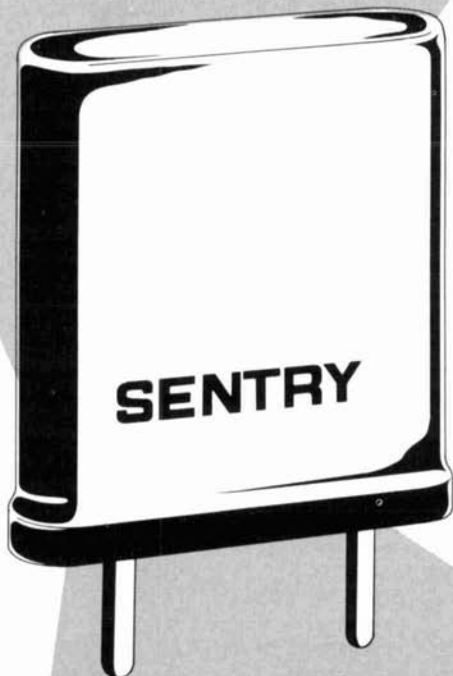

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More Details? CHECK—OFF Page 94

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General

Frequency Coverage	144-148 MHz
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Modulation	Frequency Modulation
Transmitter Control	Push-to-Talk
Power Drain	AC: Receive 6 Watts, Transmit 50 Watts DC: Receive 0.5 Amps, Transmit 4 Amps
Power Source (Built-in)	AC: 117 Volts 50-60 Hz DC: 13.5 Volts ± 10%.
Dimensions	7⅞" W x 2¾" H x 10¼" D.
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Standard Accessories	Dynamic Microphone, Hustler Antenna, Antenna Connector Plug, AC/DC Cord, Speaker Plug.

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RF Output Power	Greater than 10 Watts
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More Details? CHECK—OFF Page 94

April, 1971
volume 4, number 4

staff

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editor

Nicholas D. Skeer, K1PSR
vhf editor
J. Jay O'Brien, W6GDO
fm editor

Alfred Wilson, W6NIF
James A. Harvey, WA6IAK
associate editors

Jean Frey
art director
Wayne T. Pierce, K3SUK
cover

T. H. Tenney, Jr. W1NLB
publisher

John B. Morgan, K1RA
advertising manager

offices

Greenville, New Hampshire 03048
Telephone: 603-878-1441

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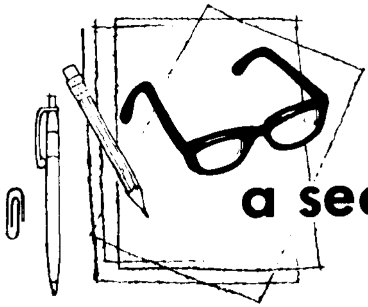

a second look

by jim fisk

new phone bands

If the FCC's newly proposed amateur radio frequency allocations are adopted, Advanced and Extra class amateurs can look forward to much wider phone bands. The new proposal, so new a number had not been assigned as of press time, provides for more operating space on all five high-frequency bands – 80, 40, 20, 15 and 10 meters. On 80 meters, for example, the Extra-class phone band would begin at 3750 kHz; the Advanced-class band would start at 3775 kHz while the General-class phone privileges would be increased to 3875 to 4000 kHz.

On the other high-frequency bands, the Extra-class phone segments would begin at 7150, 14150, 21200, and 28350 kHz. The Advanced-class phone segments would be at 3775, 7175, 14175, 21225 and 28375 kHz. Under the new plan General-class phone privileges would be expanded to start at 3875, 7225, 14250, 21325 and 28500 kHz. In addition to increased operating space on 80, 40, 20 and 15 meters, note the new Advanced and Extra class phone allocation on 10 meters.

Also included in the new FCC proposal is an all-new Advanced and Extra-class phone sub-band on 40 meters, from 7075 to 7100 kHz. This is specifically designed for radiotelephone communications between the United States and Europe and Africa. The new proposal would also reduce the width of the exclusive Extra-class CW segments on each of the high-frequency bands – from 25 to 10 kHz.

In addition, under the new plan Novices would gain an additional 100 kHz of CW operating space on 10 meters – between 28150 and 28250 kHz.

Remember, these phone bands are still in the proposal stage. For more details I suggest you listen to the W1AW broadcasts from A.R.R.L. They are able to disseminate the pertinent details much more rapidly than a monthly magazine. Next month we will publish the complete text of the FCC proposal in *ham radio*. In the meantime, consider all the ramifications of this plan, discuss it with your friends and at your local radio club, and submit your comments to the FCC before June 1, 1971 (remember that all comments must be submitted in 14 copies).

circuits and techniques

On page 34 of this issue you'll find the first installment of a new monthly column, **circuits and techniques.** This new addition to *ham radio,* written by Edward M. Noll, W3FQJ, will endeavor to keep you up to date on the latest developments in communications and electronics. In addition to state-of-the-art developments, Ed will cover little known circuits and experimental techniques that are useful to amateurs and experimenters. In many cases overseas amateurs devise solutions to electronic problems that receive little publicity in this country. Ed will be reviewing many of the foreign electronics publications in an effort to keep up to date on this phase of amateur radio.

Ed Noll is well qualified for this new assignment with *ham radio.* As a long-time radio amateur, consulting engineer and accomplished author of technical articles and books, Ed brings to *ham radio* a background of translating complex electronics ideas into easy-to-understand text. His latest book, "Solid-State QRP Projects," was recently published by Editors and Engineers.

Jim Fisk, W1DTY
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More Details? CHECK–OFF Page 94

practical vhf and uhf coil-winding data

The practical coil-winding data presented here provides complete details on inductors from 2 nanohenries to 1 microhenry

Donald Kochen, K3SVC, 1889 August Avenue, Dundalk, Maryland 21222

This article contains computer generated data for building inductors from 2 to 1000 nanohenries (1 nanohenry = .001 μH). Since no calculations are involved, it is a simple matter to scan the tables, and select the inductor that best meets your particular requirements. The first part of the article describes single-layer solenoids from 10 to 1000 nH; the last part describes straight-wire inductors above a chassis that range from 2 to 100 nH.

vhf inductors

Many vhf experimenters have developed a sixth sense for winding rf coils — they've had to, since there doesn't seem to be any convenient coil winding data for this part of the spectrum. (The ARRL Lightning Calculator stops at 1 μH and the Allied Coil Winding Calculator stops at 0.1 μH.)

The typical design procedure is to wrap some wire around a pencil (a coil form is also permitted) and trim the coil to resonance with the aid of a grid-dip meter and fixed capacitor. However, it takes a fair amount of experience to select the proper wire size and coil diameter that will give the desired inductance and still have reasonable Q and low capacitance.

Tables 1, 2, 3 and **4** describe coils of 1 to 10 turns wound with an inside diameter of 1/8 to ½ inch.* Because of their size, these coils are especially attractive for use with solid-state receivers and transmitters.

design philosophy

The goal is an inductor that has high Q, low capacitance and compact size. Low coil capacitance means the inductor will have a high self-resonant frequency, and therefore, a more useful frequency range. This can be achieved by a single-layer solenoid with adequate turns spacing. A good rule of thumb is to have a space equal to the wire diameter between adjacent turns with coil length about 1.5

*The tables were computed from the formula

$$L = \frac{\left(\frac{ND}{2}\right)^2}{4.5D + 10l} \qquad (1)$$

where L is inductance, D is coil diameter and l is coil length. This formula approximates the low-frequency inductance of a coil in free space. However, after building a few coils and measuring their inductance with a Boonton 250A RX meter at 100 MHz it appears that the error is only 10% for most coils.

times the coil diameter. The result is a coil with low capacitance and reasonable Q. All coils computed in the tables have turns spacing equal to the diameter of the wire used; as a check, the overall length of the coil is also given.

Those coils whose length is 1 to 2 times diameter are shown in bold type since they are considered to be optimum. By scanning the tables you can see that any inductance can be obtained by an optimum coil.

All calculated inductances were rounded off to the nearest 10 nanohenries. This means that the error of values below 30 nH will be ±5 nH. This seemed sufficient since adjacent objects will introduce errors into the free-space design anyway. Below 10 nH it is usually easier to build straight-wire inductors.

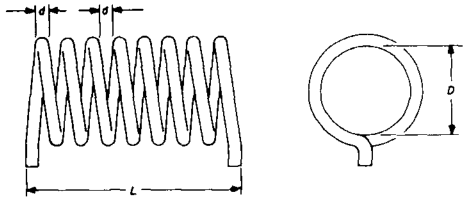

fig. 1. Airwound coil showing construction dimensions.

table 1. Coil data for 0.125-inch diameter airwound coils. Bold-face values represent optimum designs

wire size	number of turns 1	2	3	4	5	6	7	8	9	10	
18	**5**	**10**	**20**	30	30	40	50	60	70	70	nH
	.12	**.20**	**.28**	.36	.44	.52	.60	.69	.77	.85	inch
20	5	**10**	**20**	30	40	50	50	60	70	80	nH
	.10	**.16**	**.22**	.29	.35	.42	.48	.54	.61	.67	inch
22	5	**10**	**20**	**30**	40	50	60	70	80	90	nH
	.08	**.13**	**.18**	**.23**	.28	.33	.38	.43	.48	.53	inch
24	5	10	**20**	**30**	**50**	**60**	70	80	100	110	nH
	.06	.10	**.14**	**.18**	**.22**	**.26**	.30	.34	.38	.42	inch

table 2. Coil data for 0.25-inch diameter airwound coils. Bold-face values represent optimum designs.

Wire size	number of turns 1	2	3	4	5	6	7	8	9	10	
12	**10**	**20**	**30**	50	70	80	100	120	130	150	nH
	.24	**.40**	**.57**	.73	.89	1.05	1.21	1.37	1.54	1.7	inch
14	**10**	**20**	**40**	50	70	90	110	130	150	170	nH
	.19	**.32**	**.45**	.58	.71	.83	.96	1.09	1.22	1.35	inch
16	10	**20**	**40**	**60**	**80**	100	120	140	170	190	nH
	.15	**.25**	**.36**	**.46**	**.56**	.66	.76	.86	.97	1.07	inch
18	10	**30**	**50**	**70**	**90**	**120**	140	170	190	220	nH
	.12	**.20**	**.28**	**.36**	**.44**	**.52**	.60	.69	.77	.85	inch
20	10	30	**50**	**80**	**100**	**130**	**160**	**190**	220	250	nH
	.10	.16	**.22**	**.29**	**.35**	**.42**	**.48**	**.54**	.61	.67	inch
22	10	30	**60**	**90**	**120**	**150**	**180**	**220**	**250**	290	nH
	.08	.13	**.18**	**.23**	**.28**	**.33**	**.38**	**.43**	**.48**	.53	inch
24	10	30	**60**	**100**	**130**	**170**	**210**	**250**	**290**	**340**	nH
	.06	.10	**.14**	**.18**	**.22**	**.26**	**.30**	**.34**	**.38**	**.42**	inch

table 3. Coil data for 0.375-inch diameter airwound coils. Bold-face values represent optimum designs.

wire size	number of turns 1	2	3	4	5	6	7	8	9	10	
10	**10**	**30**	**60**	80	110	130	160	190	210	240	nH
	.31	**.51**	**.71**	.92	1.12	1.32	1.53	1.73	1.94	2.14	inch
12	10	**30**	**60**	**90**	120	150	180	210	240	270	nH
	.24	**.40**	**.57**	**.73**	.89	1.05	1.21	1.37	1.54	1.70	inch
14	10	**40**	**70**	**100**	**130**	170	200	240	280	310	nH
	.19	**.32**	**.45**	**.58**	**.71**	.83	.96	1.09	1.22	1.35	inch
16	10	40	**70**	**110**	**150**	**190**	**230**	270	320	360	nH
	.15	.25	**.36**	**.46**	**.56**	**.66**	**.76**	.86	.97	1.07	inch
18	10	40	80	**130**	**170**	**220**	**270**	**320**	**370**	420	nH
	.12	.20	.28	**.36**	**.44**	**.52**	**.60**	**.69**	**.77**	.85	inch
20	10	50	90	140	**190**	**250**	**310**	**360**	**420**	**480**	nH
	.10	.16	.22	.29	**.35**	**.42**	**.48**	**.54**	**.61**	**.67**	inch
22	20	50	100	160	220	**280**	**350**	**420**	**490**	**560**	nH
	.08	.13	.18	.23	.28	**.33**	**.38**	**.43**	**.48**	**.53**	inch
24	20	60	110	170	240	320	400	**480**	**560**	**650**	nH
	.06	.10	.14	.18	.22	.26	.30	**.34**	**.38**	**.42**	inch

table 4. Coil data for 0.5-inch diameter airwound coils. Bold-face values represent optimum designs.

wire size	number of turns 1	2	3	4	5	6	7	8	9	10	
10	20	**50**	**80**	**120**	160	200	250	290	330	380	nH
	.31	**.51**	**.71**	**.92**	1.12	1.32	1.53	1.73	1.93	2.14	inch
12	20	50	**90**	**140**	**180**	**230**	280	330	380	430	nH
	.24	.40	**.57**	**.73**	**.89**	**1.05**	1.21	1.37	1.54	1.70	inch
14	20	60	100	**150**	**210**	**260**	**320**	380	440	500	nH
	.19	.32	.45	**.58**	**.71**	**.83**	**.96**	1.09	1.22	1.35	inch
16	20	60	110	170	**240**	**300**	**370**	**440**	**510**	580	nH
	.15	.25	.36	.46	**.56**	**.66**	**.76**	**.86**	**.97**	1.07	inch
18	20	70	130	190	270	**340**	**420**	**500**	**590**	**670**	nH
	.12	.20	.28	.36	.44	**.52**	**.60**	**.69**	**.77**	**.85**	inch
20	20	70	140	210	300	390	**480**	**580**	**680**	**780**	nH
	.10	.16	.22	.29	.35	.42	**.48**	**.54**	**.61**	**.67**	inch
22	20	80	150	240	340	440	550	660	**780**	**900**	nH
	.08	.13	.18	.23	.28	.33	.38	.43	**.48**	**.53**	inch
24	20	80	160	260	370	490	620	750	890	1030	nH
	.06	.10	.14	.18	.22	.26	.30	.34	.38	.42	inch

example 2. A 50-nH coil is required for a 20 watt transmitter.

possibility		comment
0.125 diam	5 turns no. 24	poor choice at this power level
0.250 diam	4 turns no. 12 or no. 14	fair choice — only slightly out of optimum region
0.250 diam	3½ turns no. 16	marginal at this power level
0.250 diam	3 turns no. 18	marginal at this power level
0.375 diam	2.7* turns no. 10	good choice
0.375 diam	2.7 turns no. 12	good choice
0.375 diam	2.3 turns no. 14	good choice
0.500 diam	2 turns no. 10	good choice
0.500 diam	2 turns no. 12	good choice

example 3. Same 50-nH coil as in example 2 but this time it is required for a receiver

0.125 dia.	5 turns no. 24	good choice, compact size
0.250 dia.	3.5 turns no. 16	good choice
0.250 dia.	3 turns no. 18	good choice
0.375 dia.	2.7 turns no. 10	good choice, but large size may add too much capacitance to circuit

using the tables

The tables are intended for air-core coils whose dimensions are indicated in **fig. 1.** Each table describes coils wound with a different inside diameter. Wire size and number of turns are specified along the edge of the chart. The data within the table is inductance in nanohenries (on top) and coil length in inches (below). The use of the inductance tables is best illustrated by several practical examples.

example 1. What is the inductance of 5 turns no. 18 wire, 0.25-inch diameter, wound with spacing equal to wire diameter? From **table 2,** opposite no. 18, and below 5 turns, you find this coil has 90-nH inductance and is 0.44 inches long.

A coil of given inductance can be easily designed by scanning the optimum regions (bold-faced type) of each table. If the exact value is not found, the inductance may be mentally interpolated by changing the turns by a fraction or by compressing or expanding coil length.

uhf inductors

As you can see from **tables 1, 2, 3** and **4,** it is impractical to wind coils less than 10 nH. For less than 10 nH the inductance of a straight piece of wire is sufficient. Quarter-wavelength resonators are common in microwave work and may be considered as an inductance in parallel with distributed capacitance.

Full-sized ¼-wave resonators are useful above 1 or 2 GHz because of their convenient size and high Q. But at 432 MHz or even 1296, the designer may want a more compact resonator. This can be accomplished by shortening the length needed for ¼-wave resonance and making up for the decreased inductance by adding external capacitance.

Obviously this is a design trade-off resulting in a lower Q, since $Q = X_L/R$, and decreased inductance means lowered Q. However, you have gained more compact size: e. g., 432-MHz tank circuits may be built 1 or 2 inches long as compared with a full quarter-wavelength of 7 inches. You have also avoided an impedance-matching problem since connecting circuitry will usually be capacitive anyway. In a transistor tank circuit the collector capacitance, tuning capacitor and coil capacitance are combined. Output is taken by either capacitor-divider coupling, transformer coupling or tapping

*Instead of winding fractional turns, the coil may be wound with 3 turns and "stretched" to the desired inductance.

down on the coil. (Motorola has an excellent application note for rf transistor design.)[2]

Tables 5, 6 and **7** contain computed data describing a wire of diameter D and length L, spaced height H above a ground plane as shown in **fig. 2.*** Wire size, height above ground and length in inches are specified along the edge of the inductance tables. The data within the table is inductance (nH) on top, capacitance (pF) in the middle, self-resonance (GHz) on

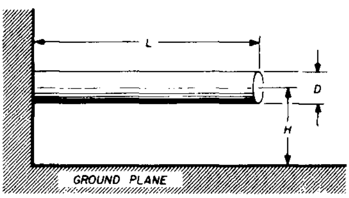

fig. 2. Length of wire above a ground plane exhibits both inductance and capacitance. Dimensions are used to calculate values.

the bottom. As before, the use of these tables is best illustrated by several typical examples.

example 4. What are the characteristics of a 2-inch length of no. 10 wire, spaced 0.25 inch above a ground plane? From **table 5,** a 2-inch length of no. 10 wire has 21-nH inductance in parallel with 0.7 pF. Self-resonant frequency 1.2 GHz (1200 MHz).

design philosophy

A quick scan of **tables 5, 6** and **7** reveals some interesting phenomena that should be kept in mind when laying out circuits. For example, moving the inductor closer to a ground plane increases its capacitance. Not so obvious is the fact that this also decreases inductance. The inductor and the ground plane may be considered to be a transformer with a shorted secondary. Hence, increased coupling results in less inductance. It turns out that the capacitance changes more than inductance, and the net result is a lower resonant frequency.

Moving the inductor away from the chassis will raise the Q. Beyond a height of one inch, however, the computed L and C rapidly approaches the free-space inductance as a limit, and the law of diminishing returns applies.

Considering the resonator as a transmission line, its characteristic impedance is $Z_O = \sqrt{L/C}$. Thus, moving the ¼-wave resonator too far from the chassis will raise its impedance to match the approximately 377-ohm radiation resistance of space. Then the resonator will then behave more like an antenna than a resonator.

Adding additional ground planes at right angles to form a coaxial cavity around the wire lowers the resonant frequency by about 10%. This implies that L and C have changed by more than that amount since they move in opposite directions. An estimate of the inductance and capacitance of a coaxial shielded wire can be made by considering it simply as a wire that is closer to a single ground plane.

*The inductance values shown in **tables 5, 6** and **7** were calculated from the formula

$$L = .0116967 \left(\log 4H/D + \log \frac{A}{B}\right) + .00508 \left(B - A + \mu 1 \delta - 2H + \frac{D}{2}\right)$$

$$\text{where } A = 1 + \sqrt{1^2 + \frac{D^2}{4}}$$

$$B = 1 + \sqrt{1^2 + 4H^2}$$

$$\mu \text{ (permeability)} = 1$$

Skin effect, because of its very small value, was neglected. The capacitance of the straight wire above a ground plane was calculated from

$$C = \frac{\pi \epsilon l}{\ln \left(\frac{4H}{D} - 1\right)}$$

where ϵ is permitivity. As a check, capacitance measurements were made on a Boonton 250A RX meter operating at 1 MHz. Readings were within 0.4 pF of the calculated values.

Next, the circuit of **fig. 2** was duplicated, and a signal generator and rf detector were loosely coupled to the resonator. For each case measured the self-resonant frequency was within 20% of that calculated from the computed inductance and capacitance. It is also gratifying that there is some correlation between the computed LC resonant frequency and resonance of ¼-wave transmission lines.

table 5. Inductance of wire 0.25 inch above a ground plane. Upper value is inductance in nH, middle value is capacitance in pF, lower value is self-resonant frequency in GHz.

wire	length (inches)										
size	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	
	2	5	9	12	15	19	22	26	29	33	nH
2	.4	.7	1.1	1.5	1.8	2.2	2.5	2.9	3.3	3.6	pF
	5.3	2.4	1.5	1.1	.9	.7	.6	.5	.5	.4	GHz
	3	6	10	14	18	22	26	30	34	38	nH
4	.3	.6	.8	1.1	1.4	1.7	2	2.3	2.5	2.8	pF
	5.4	2.4	1.6	1.2	.9	.8	.6	.6	.5	.4	GHz
	3	7	12	17	21	26	30	35	40	44	nH
6	.2	.5	.7	.9	1.2	1.4	1.6	1.9	2.1	2.3	pF
	5.5	2.5	1.6	1.2	.9	.8	.7	.6	.5	.5	GHz
	4	9	14	19	24	29	34	40	45	50	nH
8	.2	.4	.6	.8	1	1.2	1.4	1.6	1.8	2	pF
	5.5	2.5	1.6	1.2	.9	.8	.7	.6	.5	.5	GHz
	4	10	15	21	27	33	38	44	50	56	nH
10	.2	.4	.5	.7	.9	1.1	1.2	1.4	1.6	1.8	pF
	5.4	2.5	1.6	1.2	1	.8	.7	.6	.5	.5	GHz
	5	11	17	23	30	36	42	49	55	62	nH
12	.2	.3	.5	.6	.8	.9	1.1	1.3	1.4	1.6	pF
	5.4	2.5	1.6	1.2	1	.8	.7	.6	.5	.5	GHz
	5	12	19	26	33	40	47	54	61	67	nH
14	.1	.3	.4	.6	.7	.9	1	1.1	1.3	1.4	pF
	5.4	2.5	1.6	1.2	1	.8	.7	.6	.5	.5	GHz
	6	13	21	28	36	43	51	58	66	73	nH
16	.1	.3	.4	.5	.7	.8	.9	1	1.2	1.3	pF
	5.3	2.5	1.6	1.2	1	.8	.7	.6	.5	.5	GHz
	6	14	22	30	38	47	55	63	71	79	nH
18	.1	.2	.4	.5	.6	.7	.8	1	1.1	1.2	pF
	5.3	2.5	1.6	1.2	1	.8	.7	.6	.5	.5	GHz
	7	15	24	33	41	50	59	68	76	85	nH
20	.1	.2	.3	.5	.6	.7	.8	.9	1	1.1	pF
	5.3	2.5	1.6	1.2	1	.8	.7	.6	.5	.5	GHz
	7	17	26	35	44	54	63	72	82	91	nH
22	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.1	pF
	5.2	2.5	1.6	1.2	1	.8	.7	.6	.5	.5	GHz
	8	18	27	37	47	57	67	77	87	97	nH
24	.1	.2	.3	.4	.5	.6	.7	.8	.9	1	pF
	5.2	2.5	1.6	1.2	1	.8	.7	.6	.5	.5	GHz

Uhf resonators are usually made from the larger diameter wires, but data for wires smaller than no. 18 is included mainly for estimating component-lead inductance. The resonant frequency given in the tables sets the upper limit at which the inductor may be used; above resonance it acts like a capacitor. The inductor should be chosen so that with the added external circuit capacitance the LC combination will resonate at the desired frequency.

example 5. It is desired to design a transistor tank circuit for 430 MHz as shown in **fig. 3.** The transistor has an output capacitance of 3 pF, and

table 6. Inductance of wire 0.5 inch above a ground plane. Upper value is inductance in nH, middle value is capacitance in pF, lower value is self-resonant frequency in GHz.

wire	length (inches)										
size	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	
	3	7	12	17	22	27	32	38	43	48	nH
2	.2	.4	.6	.8	1	1.2	1.4	1.6	1.8	2	pF
	6.3	2.7	1.7	1.3	1	.8	.7	.6	.5	.5	GHz
	3	8	14	19	25	31	36	42	48	54	nH
4	.2	.4	.5	.7	.9	1.1	1.2	1.4	1.6	1.8	pF
	6.2	2.7	1.7	1.3	1	.8	.7	.6	.5	.5	GHz
	4	9	15	21	28	34	40	47	53	59	nH
6	.2	.3	.5	.6	.8	.9	1.1	1.3	1.4	1.6	pF
	6.1	2.7	1.7	1.3	1	.8	.7	.6	.5	.5	GHz
	4	10	17	24	31	37	44	51	58	65	nH
8	.1	.3	.4	.6	.7	.9	1	1.1	1.3	1.4	pF
	6	2.7	1.7	1.3	1	.8	.7	.6	.5	.5	GHz
	5	11	19	26	33	41	48	56	64	71	nH
10	.1	.3	.4	.5	.7	.8	.9	1.1	1.2	1.3	pF
	5.9	2.7	1.7	1.3	1	.8	.7	.6	.5	.5	GHz
	5	13	20	28	36	44	53	61	69	77	nH
12	.1	.2	.4	.5	.6	.7	.8	1	1.1	1.2	pF
	5.8	2.7	1.7	1.2	1	.8	.7	.6	.5	.5	GHz
	6	14	22	31	39	48	57	65	74	83	nH
14	.1	.2	.3	.5	.6	.7	.8	.9	1	1.1	pF
	5.8	2.6	1.7	1.2	1	.8	.7	.6	.5	.5	GHz
	6	15	24	33	42	51	61	70	79	89	nH
16	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.1	pF
	5.7	2.6	1.7	1.2	1	.8	.7	.6	.5	.5	GHz
	7	16	26	35	45	55	65	75	85	94	nH
18	.1	.2	.3	.4	.5	.6	.7	.8	.9	1	pF
	5.6	2.6	1.7	1.2	1	.8	.7	.6	.5	.5	GHz
	7	17	27	38	48	58	69	79	90	100	nH
20	.1	.2	.3	.4	.5	.6	.7	.7	.8	.9	pF
	5.6	2.6	1.7	1.2	1	.8	.7	.6	.5	.5	GHz
	8	18	29	40	51	62	73	84	95	106	nH
22	.1	.2	.3	.4	.4	.5	.6	.7	.8	.9	pF
	5.5	2.6	1.7	1.2	1	.8	.7	.6	.5	.5	GHz
	9	19	31	42	54	65	77	89	100	112	nH
24	.1	.2	.3	.3	.4	.5	.6	.7	.8	.8	pF
	5.5	2.6	1.7	1.2	1	.8	.7	.6	.5	.5	GHz

the two impedance-matching variable, capacitors are assumed to present an average capacitance of 4 pF at the collector. Thus, total capacitance will be 7 pF plus inductor capacitance. An LC nomograph (**fig. 4**) indicates that 20 nH will resonate with 7 pF at 425 MHz.

The date for no. 14 wire spaced 0.25 inch above a ground plane (**table 5**) shows that a 1½-inch length has 17-nH inductance and 10.5 pF capacitance. Therefore, the tank circuit consists of 19 nH in parallel with 17.4 pF and has a midrange resonance of 424 MHz.

table 7. Inductance of wire 1.0 inch above a ground plane. Upper value is inductance in nH, middle value is capacitance in pF, lower value is self-resonant frequency in GHz.

wire	length (inches)									
size	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	
	3	8	14	21	27	34	41	47	54	61	nH
2	.1	.3	.4	.6	.7	.9	1	1.1	1.3	1.4	pF
	7.1	3	1.9	1.3	1	.9	.7	.6	.6	.5	GHz
	3	9	16	23	30	37	45	52	59	67	nH
4	.1	.3	.4	.5	.7	.8	.9	1.1	1.2	1.3	pF
	6.9	3	1.8	1.3	1	.9	.7	.6	.6	.5	GHz
	4	10	18	25	33	41	49	57	65	73	nH
6	.1	.2	.4	.5	.6	.7	.8	1	1.1	1.2	pF
	6.7	2.9	1.8	1.3	1	.8	.7	.6	.6	.5	GHz
	4	11	19	27	36	44	53	61	70	78	nH
8	.1	.2	.3	.5	.6	.7	.8	.9	1	1.1	pF
	6.5	2.9	1.8	1.3	1	.8	.7	.6	.5	.5	GHz
	5	13	21	30	39	48	57	66	75	84	nH
10	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.1	pF
	6.4	2.8	1.8	1.3	1	.8	.7	.6	.5	.5	GHz
	5	14	23	32	41	51	61	71	80	90	nH
12	.1	.2	.3	.4	.5	.6	.7	.8	.9	1	pF
	6.3	2.8	1.8	1.3	1	.8	.7	.6	.5	.5	GHz
	6	15	24	34	44	55	65	75	86	96	nH
14	.1	.2	.3	.4	.5	.6	.7	.7	.8	.9	pF
	6.2	2.8	1.8	1.3	1	.8	.7	.6	.5	.5	GHz
	7	16	26	37	47	58	69	80	91	102	nH
16	.1	.2	.3	.4	.4	.5	.6	.7	.8	.9	pF
	6.1	2.8	1.8	1.3	1	.8	.7	.6	.5	.5	GHz
	7	17	28	39	50	62	73	85	96	108	nH
18	.1	.2	.3	.3	.4	.5	.6	.7	.8	.8	pF
	6	2.7	1.7	1.3	1	.8	.7	.6	.5	.5	GHz
	8	18	30	41	53	65	77	89	101	114	nH
20	.1	.2	.2	.3	.4	.5	.6	.6	.7	.8	pF
	5.9	2.7	1.7	1.3	1	.8	.7	.6	.5	.5	GHz
	8	19	31	44	56	69	81	94	107	119	nH
22	.1	.2	.2	.3	.4	.5	.5	.6	.7	.8	pF
	5.8	2.7	1.7	1.3	1	.8	.7	.6	.5	.5	GHz
	9	21	33	46	59	72	85	99	112	125	nH
24	.1	.1	.2	.3	.4	.4	.5	.6	.7	.7	pF
	5.8	2.7	1.7	1.3	1	.8	.7	.6	.5	.5	GHz

summary

It is one thing to design on paper but uhf and microwave work always require a certain amount of "cut and try." The approximations made and factors ignored in this article would probably send chills up the spine of a physicist. However, physicists don't have to design equipment and make things work.

Each piece of equipment is a unique problem. Armed with basic data and some mental fudge factors the designer can obtain a quick solution of reasonable

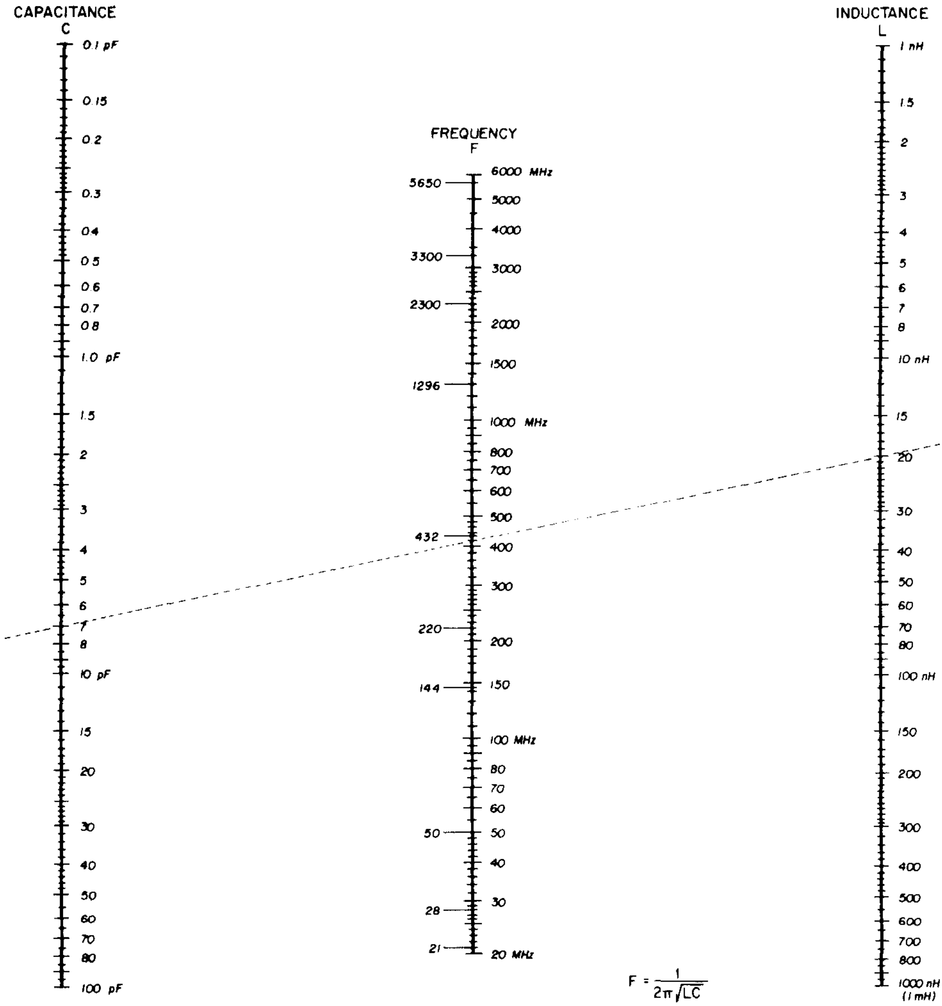

fig. 4. Resonant-frequency nomograph may be used to determine capacitor and inductor values over the range from 20 to 6000 MHz. The example indicates that 20 nH will resonate at 425 MHz with a 7-pF capacitor.

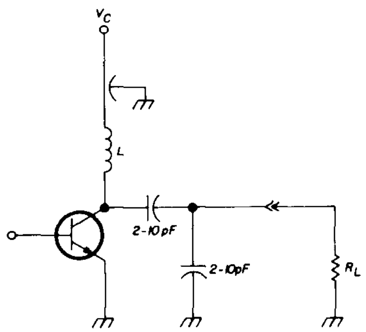

fig. 3. Typical 425-MHz tank circuit. Effective circuit capacitance of 7.4 pF will resonate with 19 nH at 424 MHz.

accuracy. Compared to that, an exact calculation is usually impractical.

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ham radio

how to use ferrite and powdered-iron for inductors

A complete description of ferromagnetic rods, toroid cores, pot cores, and broadband transformers, and how to use them in your circuits

Hank Olson, W6GXN, Post Office Box 339, Menlo Park, California 94025

"Just another hunk of Detroit Iron," says the sports-car buff as he is passed by a new Camaro. Detroit does use a good deal of iron in the manufacture of automobiles, but glass, plastics and nonferrous metals are replacing it in increasing quantities.

In electronics too, the drive is on to eliminate the iron and get everything down to one 100 x 100-mil silicon chip. Countless articles have been written on how to eliminate inductors (and their iron) from resonant circuits. Because of these efforts there have been some notable successes in replacing inductors with capacitors by means of feedback techniques.

I praise these new techniques, not as replacements for iron, but as welcome *additions* to the engineering bag of tricks. With the new all-silicon techniques, we can now come up with solutions to problems that were once the job for large iron components. Furthermore, these new techniques solve problems that iron could never be expected to touch. If you adopt this view you gain engineering flexibility and can solve any given problem the *best* way (although the use of iron may be the best way).

A brief look at conventional transformers and chokes will help you understand some of the basics. Any experimenter who has taken a transformer or choke apart (either for curiosity or rewinding purposes) is aware that such devices are made of laminated steel sections. These laminations are generally in two forms, some resembling the letter E and some the letter I. This is called the E-I core. The careful disassembler probably also noted that the E and I sections in a swinging choke or transformer were stacked as shown in **fig. 1A;** smoothing-choke E and I sections use the arrangement of **fig. 1B** with the addition of a small piece of cardboard. If you ever tried reassembling the transformer, you probably found that it ran hotter than the original, even when no more power was being transformed.

magnetic circuits

To understand some of these observations, it might be a good idea to review a few basics of magnetic circuits. There are a number of ferro-magnetic substances, including iron, nickel and cobalt. These materials have a peculiar characteristic, that of high μ.

The concept of μ (mu) can be explained qualitatively by a simple experiment. Wind a coil of 50 turns of number-24 enameled wire on a cardboard mailing tube and measure its inductance. It should come out in the neighborhood of 80 μH. Now insert a ferrite rod from an old transistor radio antenna into the coil; you should see the inductance increase dramatically. While this is not a rigid definition of μ, it will give you a feel of its effect.

Another useful magnetic concept is that of reluctance. If you can envision the presence of the ferrite rod in our experimental coil as providing a low-impedance path for the magnetic field lines that flow axially inside the coil, reluctance *is* that impedance. Since magnetic field lines always close on themselves (flowing from north pole to south pole inside the coil and back again on the outside) it would seem that we could further reduce reluctance by continuing our ferrite rod around the outside of the coil as in **fig. 2B,** thereby increasing inductance. In fact, this is true, and the result *is* a coil with more inductance.

The E-I construction is simply an extension of the technique of **fig. 2B** where *two* low-reluctance return paths are used in parallel outside the coil as in **fig. 2C.** A modern version of fig. 2B can be found in tape-wound C core or toroid used in 400-Hz power transformers and dc-to-dc converters.

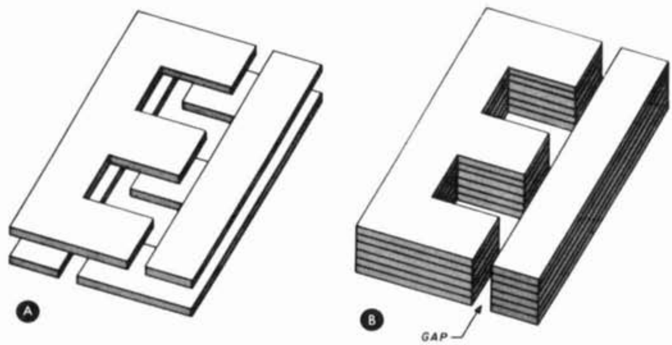


fig. 1. E-I transformer cores. Drawing in A shows how laminations are interleaved for minimum reluctance. B shows stacking of smoothing-choke laminations for insertion of cardboard air gap between E- and I-sections.

The mystery of why the rewound transformer ran hot can be understood in terms of eddy current loss. If the iron core was made of one *solid* piece of steel eddy-current loss would be very high. This occurs because the steel is an electrical conductor, and appears as a shorted turn in the same plane as the turns of the transformer winding. Such shorted turns are broken up by insulating layers between a laminated core – usually with some sort of varnish. In disassembly and reassembly of an E-I transformer core, the varnish is partially removed. Unless the reason for the varnish is understood, and it is replaced, the rewound transformer will run hot.

As transformers were called on to handle higher and higher frequencies it was found that the thickness of the laminations had to be made smaller. The reason for this is easily appreciated if we consider that the inductive reactance of a shorted turn goes up with frequency. Thus, at higher frequencies a small diameter shorted turn can give the same inductive reactance as a large diameter shorted turn at lower frequencies.

The tape-wound cores that are available now have lamination thickness down to ¼ mil, and operate efficiently up to several thousand cycles per second. Of course, the thickness of the inter-lamination insulation must be decreased at the same rate as the laminate. Otherwise the amount of magnetic material per unit volume in the core will be decreased. Such a decrease in magnetic material per unit volume would lower the μ of the core.

Since the early days of telephone another type of magnetic core has been in use — the powdered-iron toroid. This form was suggested before 1900 by Oliver Heavyside as a solution to eddy-current loss.[1] By coating iron filings with insulation and compressing them into a doughnut shape, a non-conductive, closed-magnetic structure is created that is useful to fairly high frequencies. However, this technique also has its limitations because the size of the iron particles must decrease at higher frequencies, as must the thickness of the insulating coating.

ferrite

Ferrite is a relatively new material to be used in magnetic cores. Since ferrites are not pure metals like iron, nickel or cobalt they do not have high electrical conductivity. In fact, ferrites are made mostly of iron oxide plus some additive such as manganese; they are sintered at high temperature and become ceramic-like — hard and difficult to modify after formation. Because of their low bulk conductivity, they offer nearly ideal high-frequency core characteristics: low eddy-current loss *and* high μ.

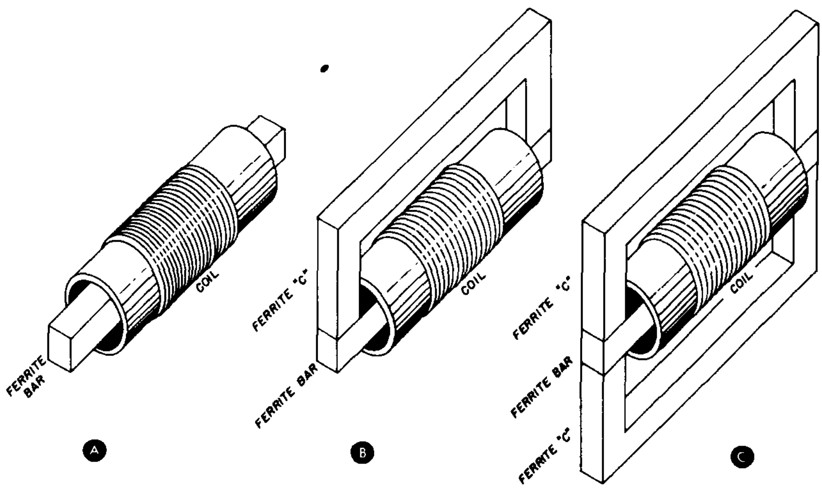


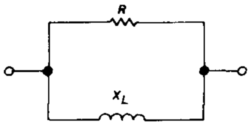
fig. 2. Inductance of simple coil is increased by ferrite core in A. By reducing the reluctance path as shown in B and C, inductance is further increased.

ferrite beads

The prospect of winding thousands of turns of fine wire on toroids, varnishing and restacking E-I sections, and doing other disagreeable tasks has probably discouraged most amateurs from ever building their own magnetic components. However, at audio frequencies and higher the situation is completely changed with modern magnetic cores. A useful ferrite-core choke can be simplified to a single turn! This, of course, reduces winding to a trivial business. The example I refer to is the ferrite bead.

Ferrite beads are made by several companies, but the beads most available

table 1. Equivalent parallel resistance and inductive reactance of Amidon Associates ferrite shielding beads (measured on Boonton 250A RX meter).



frequency (MHz)	resistance (ohms)	inductive reactance (ohms)
29	26.5	j43
50	29.7	j61
100	32.3	j80
144	33.4	j82
220	35.7	j72

to hams are sold in packets by Amidon Associates. The Amidon beads are useful for a host of choking applications; you simply slip a bead over a wire, and the wire becomes an rf choke. The nice thing about this rf choke is that it has very low Q, and is unlikely to create any nasty parasitic resonant circuits.

As an example, consider **fig. 3** which represents a B+ decoupling system for two stages of an rf unit. The two 1000-pF feedthrough capacitors with one inch of number-20 bare hookup wire between them form a parasitic resonance at about 45 MHz, and assure that adjacent stages are well coupled at that frequency. In a case where oscillation was rampant the simple expedient of slipping a ferrite bead over the wire cured the problem.

What strange properties do these little beads have to effect such a cure? You find the answer when you measure one on a wire; the results are shown in **table 1.** Other beads (such as those made by Ferroxcube, Ferronics and Stackpole) behave similarly but they are not readily available except in large production quantities.

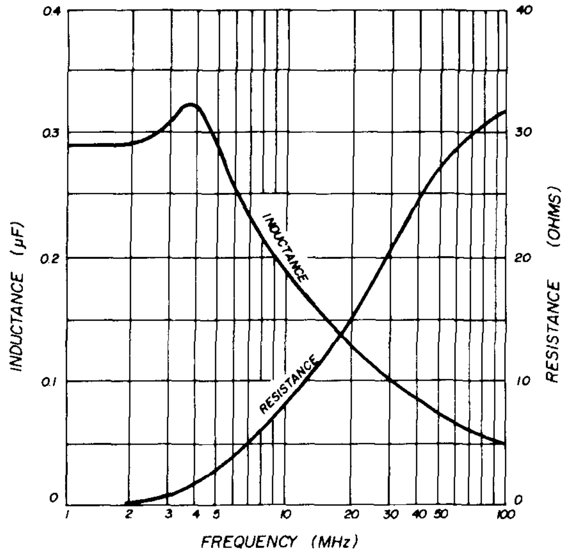


fig. 5. Typical values of equivalent series resistance and inductance for Ferronics ferrite beads.

The fact that a typical bead and wire looks like a parallel combination of 35-ohms resistance and 75-ohms inductive reactance (35 + j75) is reminiscent of the 47-ohm resistor with a small coil wound on it for a plate or grid parasitic choke. Substituting a ferrite bead for a parasitic choke is just as satisfactory in practice as it appears to be in theory.

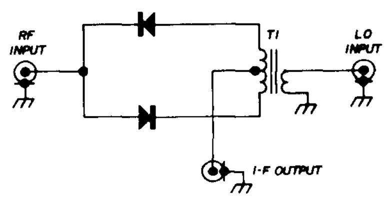


fig. 4. Simple balanced mixer using a ferrite-bead core. T1 is three turns no. 32 wire, trifilar wound on Amidon Associates ferrite bead. Two windings are cross connected to form center-tapped section. Diodes are Hewlett-Packard 5082-2800 or Motorola MBD101 (preferably matched).

Beads are immensely useful for interstage decoupling at hf through uhf,

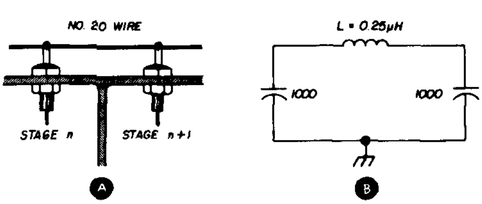


fig. 3. Typical B+ decoupling system is resonant at 45 MHz. Equivalent circuit is shown in B.

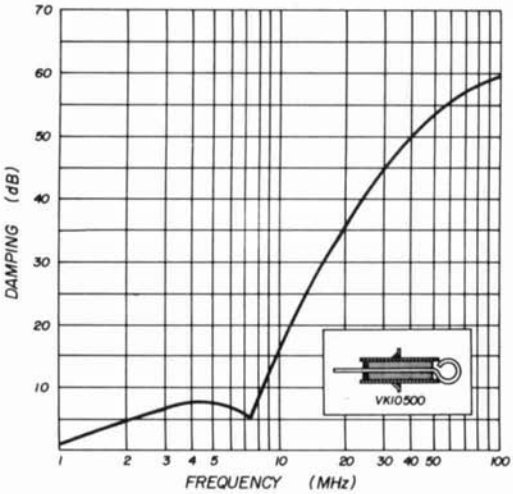


fig. 6. Performance of a Ferroxcube VK10500 decoupling filter when measured with a load impedance of 50 ohms.

powercord line decoupling, suppressing rf oscillations in audio and dc circuitry, and even in logic circuitry for decoupling splinters and spikes that cause logic blocks to communicate with each other. I've even used a ferrite bead as a tiny pulse transformer to create *very* short pulses in a blocking oscillator.[2,3] **Fig. 4** shows a simple balanced mixer for vhf using a ferrite-bead core. There may be *better* cores for balanced (or doubly-balanced) mixers but none as inexpensive.[4]

More complex forms of shielding beads are also available as commercial items. Longer cylinders of ferrite are available from Ferroxcube, Stackpole, Siemens and Allen Bradley, with various numbers of axial holes in them. For instance, a Ferroxcube 56-390-31/4B two-hole bead could be used to decouple two filament leads.

You can insert a string of beads on a wire into a metal tube or section of copper braid for a lossy coaxial line that can be used for a really broadband rf rejection filter.[5] Different companies have different ways of specifying the performance of ferrite beads, but most of these specifications are of little direct use. The Ferronics beads are described by a simple graph showing the equivalent series R and L versus frequency of one bead (21-030-F) on a piece of number-20 wire. This is shown in **fig. 5.** Note that L decreases above 4 MHz, but since inductive reactance is proportional to frequency, it is held more or less constant.

A number of companies offer a combination ferrite bead and feedthrough capacitor for decoupling purposes. This low-pass L-network is very compact and effective if used properly. A curve of the Ferroxcube VK10500 is shown in **fig. 6.** The only precaution when using these devices is to get them in the right end-for-end configuration. **Fig. 7** shows the correct and incorrect ways of using them. This is so the filter is in the LC, LC sequence required for a low-pass filter. When used incorrectly the two capacitances are connected with a piece of wire between them that results in a parasitic resonant circuit just as in **fig. 3.**

Many other types of ferrite cores are available besides beads. Toroids, pot cores, E-I combinations, U-I combinations, rods, binocular cores and many others produced by U. S., European and Japanese firms.

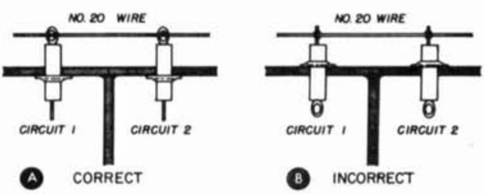


fig. 7. Correct use of Ferroxcube VK10500 decoupling filter is shown in A. Incorrect installation in B results in parasitic resonant circuit as in fig. 3.

toroid cores

The toroid is perhaps most familiar to hams.[6] However, it has several limitations; it is hard to wind (you need a bobbin or special toroid winding machine), and it is only available as a *closed* magnetic structure. The closed magnetic structure gives minimum reluctance, and hence the largest inductance per turn-squared, but is easily saturated. The closed magnetic structure is similar to the *swinging* choke (which has no air gap) and E-I transformer. To avoid saturation, toroids are used in applications where very little dc current flows through the coils wound on them. This means that you'll find wide use of toroid inductors in audio preamps (in low- or band-pass filters), in receiver tuned circuits and in low power transmitter stages.

The really nice thing about toroids is their inherent magnetic shielding, since they have a closed magnetic structure. The entire magnetic field is virtually confined inside the toroid core *if you stay well below saturation.* This means that multistage filters and amplifiers can be built with toroid inductors without much concern for coupling between them (with the resultant instability). However, capacitive coupling between toroid coils must still be considered. This extreme magnetic field confinement is most apparent when you try to couple a grid-dip meter to a toroid inductor – and generally fail.

Until fairly recently ferrite and powdered-iron toroids were not available for frequencies above a few hundred kilohertz. Now, however, ferrites are available

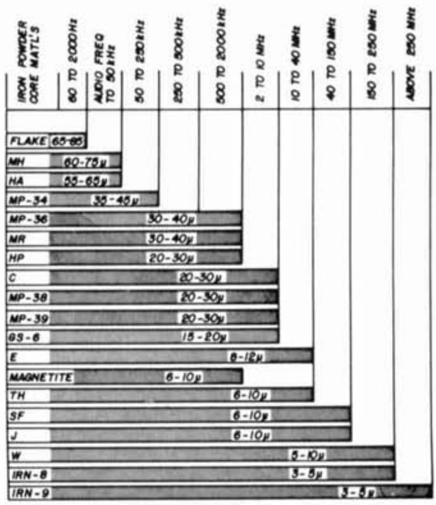


fig. 9. Frequency ratings for Arnold Engineering toroid-core materials.

that are useful into the GHz range, and powdered iron available for use up to several hundred MHz.

Let's look at a few examples. Amidon Associates* markets most of the powdered-iron toroids manufactured by Micro-Metals. They have toroids that are molded of types 2, 6, and 10 mixes, as designated by Micro-Metals. These mixes are all carbonyl types. Carbonyl is the chemical name for a compound formed of some substance and a carbon mon-

table 2. Identification of Micro-Metals core materials.

mix number	basic iron powder	color code
1	Carbonyl C	blue
2	Carbonyl E	red
3	Carbonyl HP	gray
4	Carbonyl J	blue and white
5	Carbonyl L	brown
6	Carbonyl SF	yellow
7	Carbonyl TH	white
8	Carbonyl GQ4	orange
10	Carbonyl W	black
12	IRN 8	green and white
13	IRN 9	green and red
15	Carbonyl GS6	red and white
19	electrolytic	—
22	flake	green and orange
41	hydrogen reduced	green
42	hydrogen reduced	—

*Amidon Associates, 12033 Otsego Street, North Hollywood, California 91607.

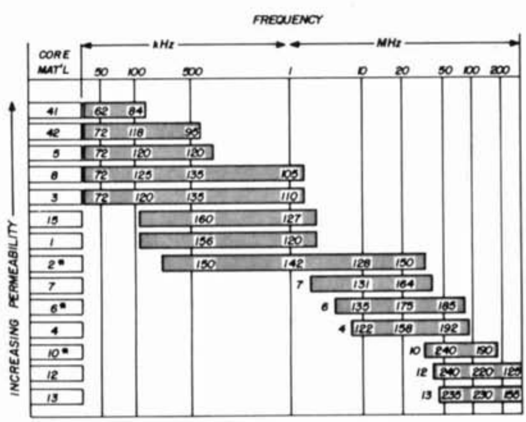


fig. 8. Frequency ratings for Micro-Metals toroid cores. Asterisked core-material mix numbers are available from Amidon Associates. Numbers on bars are Q readings.

table 3. Typical toroid-core winding data for Micro-Metals cores available from Amidon Associates.

core	wire size (AWG)	number of turns	inductance (μH)	frequency (MHz)	Q
T-94-2	30	125	130.0	0.90	232
	15/44 litz	200	328.0	0.78	278
	15/44 litz	400	1420.0	0.37	276
T-80-2	20	36	7.8	4.0	280
	26	80	37.0	2.5	246
	34	220	276.0	0.8	188
T-68-2	20	26	3.9	5.5	260
	28	79	33.0	2.5	240
	34	197	192.0	1.0	190
T-50-2	20	19	2.08	6.4	207
	30	79	33.0	2.3	200
	32	200	218	0.4	124
T-37-2	20	12	0.64	8.0	158
	24	22	2.16	7.0	170
	26	28	3.34	6.0	183
T-25-2	26	14	0.72	12.0	136
	30	30	3.22	8.0	162
	36	65	14.5	5.0	148
T-12-2	28	9	0.19	21.0	75
	32	17	0.65	15.0	84
	40	40	3.37	10.0	85
T-94-6	16	25	4.7	5.0	350
	20	20	3.0	6.0	340
	20	35	8.7	3.0	339
T-80-6	16	20	1.88	9.0	317
	20	15	1.1	10.0	255
	20	28	3.6	6.0	299
T-68-6	20	23	2.42	10.0	304
	20	15	1.08	10.0	270
	22	33	5.1	6.0	305
T-50-6	18	14	0.86	14.0	252
	22	25	2.60	10.0	260
	26	42	7.5	6.0	244
T-37-6	20	12	0.48	18.0	181
	22	17	0.97	14.0	194
	26	28	2.45	10.0	195
T-5-6	24	10	0.30	21.0	152
	28	20	1.10	15.0	164
	36	67	11.7	6.0	138
T-12-6	30	11	0.23	25.0	92
	34	18	0.56	20.0	90
	36	25	1.06	15.0	96
T-50-10	20	10	0.37	25.0	178
	20	15	0.81	18.0	190
	22	20	1.38	13.0	188
T-37-10	20	8	0.20	30.0	138
	22	15	0.61	20.0	165
	26	25	1.54	15.0	162
T-25-10	22	7	0.12	45.0	135
	24	9	0.18	35.0	141
T-12-10	28	7	0.06	60.0	120
	30	11	0.16	40.0	101
	32	14	0.26	35.0	87

oxide molecule; all three ferromagnetic metals form such carbonyls: $Fe(CO)_5$, $Ni(CO)_4$ and $Co_2(CO)_8$.

The Micro-Metals cores available from Amidon Associates, mixes 2, 6, and 10, are identified as carbonyl E, carbonyl SF, and carbonyl W. The same carbonyls are listed by Arnold Engineering Company in their catalogs. **Fig. 8** shows the general frequency range of usefulness for Micro-Metals materials, and a similar chart published by Arnold is shown in **fig. 9. Table 2** identifies the Micro-Metals mix number with the more commonly used name; e. g., carbonyl E and mix number 2 are the same. As you can see the graphical representations are in general agreement; differences reflect details of material use.

Table 3 shows the performance of toroid cores available from Amidon Associates, and should give you a good feel for which core to use at a given frequency. These point values were apparently extracted from Micro-Metals' "Engineers Aide Handbook" which is more complete, giving continuous curves of Q vs frequency for each core with different numbers of turns. This handbook is very nice, but it costs $10.00; **table 3** will probably suffice for most amateur designers. **Fig. 10** is an example of how the Micro-Metals handbook treats a typical core.

The surprising thing about coils wound on powdered-iron toroids is their Q. Note that Qs of several hundred are quite typical. The only other coils that give such high Q are air-wound types such as B&W Miniductor or Airdux (and then only when they're not too close to the chassis or in special high-conductivity shield cans).

Toroids are also available in ferrite material. You will find that ferrite toroids provide coils that have much larger inductance for a given number of turns because the ferrites have a much higher effective μ then the powdered irons. For comparison purposes consider a Micro-Metals T-44-6 which has an inductance of 0.5 μH for 10 turns. A similar sized ferrite core of Q1 material (Indiana General CF103) with the same number of turns will provide

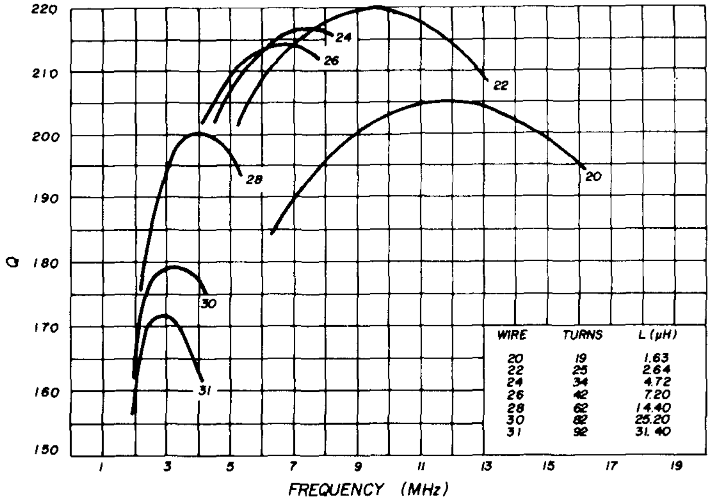


fig. 10. Winding data for Micrometals T-50-6 toroid core.

table 4. Performance of Amidon balun kit as measured with Boonton 250A RX meter. For this data a 200-ohm carbon resistor was used as *a balanced load.*

frequency (MHz)	resistance (ohms)	parallel X_L
3.5	53.8	+j90
7	53.0	+j112
14	52.5	+j204
29	49.6	+j220
50	44.5	+j122

inductance of 3 µH.

This fact would seem to be all on the positive side; large inductance coils with few turns. But it's not all "beer and skittles!" Since one turn difference in the coil can cause such a large change in inductance, it is difficult to achieve an *exact* inductance value (there's no such thing as a half turn in a toroid coil). Also, it turns out that ferrite coils have a rather severe variation of both inductance *and* Q with temperature.

The ferrite cores that are most easily obtainable in small quantity are Indiana General types. A good representation of the Indiana General catalog is carried by Newark Electronics in their 1971 mail-order catalog.

One of the more popular applications for large diameter toroid cores is as balanced-to-unbalanced transformers (baluns) for antennas. The Amidon balun kit is a typical example. The performance of this kit, connected as a 4:1 balun, is shown in **table 4** (balun winding consisted of 14 turns bifilar-wound number-14 wire).

ferrite-core rf choke

Ferrite rods are commonly used as cores for high-current rf filament chokes. A typical example is the filament-choke kit available from Amidon Associates that uses a 12 X 100 mm ferrite-rod core. With the two bifilar windings connected in parallel (as used in a typical circuit) it has 26-µH inductance. This represents 500-ohms at 3.5 MHz, or ten times the usual 50-ohm driving impedance.

To test the choke I mocked up a typical linear amplifier using two grounded-grid 811As in parallel. Total capacitance to grid was 23 pF; this gives a parallel resonance at 6.5 MHz that was confirmed with a grid-dip meter. Between

table 5. Characteristics of the Amidon Associates ferrite-core filament choke.

frequency (MHz)	parallel capacitance (pF)	parallel resistance (ohms)	equivalent parallel reactance
7	17.5	∞	−j1500
14	18.7	35k	−j600
21	23.6	25k	−j330
28	24.5	25k	−j240

table 6. International standardized pot-core sizes.

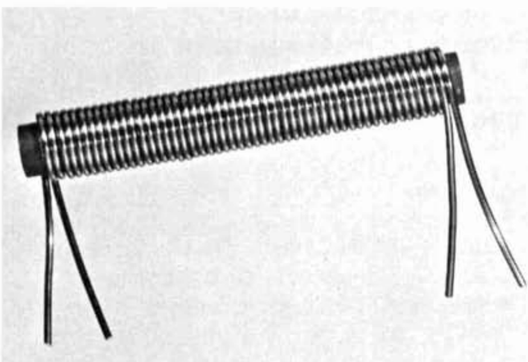
diameter (mm)	height (mm)	Siemens part	Indiana General part	TDK part	Nippon Electric part	Magnetics Inc. part	Ferroxcube part
9	5	65 521	--	--	--	40905	--
11	7	65 531	--	--	--	41107	1107P
14	8	65 541	TC1-01	P14/8	P14/8	41408	1408P
18	11	65 551	TC1-02	P18/11	P18/11	41811	1811P
22	13	65 661	TC1-03	P22/13	P22/13	42213	2213P
26	16	65 671	TC1-04	P26/16	--	42616	2616P
30	19	65 701	TC1-05	P30/19	--	43019	3019P
36	22	65 611	TC1-06	--	--	43622	3622P

6.5 and 30 MHz I could find no parallel resonant points with the grid dipper. Performance of the filament choke, as measured with a Boonton RX meter, is shown in **table 5.**

pot cores

To cut down the high effective μ and temperature coefficient of ferrite-wound coils, they are usually wound on gapped cores. The most common gapped ferrite core is the pot core. This form is particularly nice because the gap is in the center post where it does not couple to the outside world. Furthermore, most pot cores have a slug available that can be adjusted in the gap to vary inductance by ± 5%. Another advantage is gained with pot cores: The core comes in two matched halves; the coil form may be easily wound and then inserted into the core halves. There are various clamping arrangements for holding pot-core halves together; each manufacturer has his own mechanical technique.

Amidon Associates ferrite-core rf choke.



Fortunately, there has been some standardization in pot-core sizes. Since they seem to be of European origin the sizes are all in millimeters. **Table 6** shows the standard pot core sizes. Also, a uniform method of designating what inductance a gapped pot core of so many turns will produce has been adopted by manufacturers. The AL core number designates nanohenries per turn-squared. A nanohenry is 1/1000 of one μH; the rating is per turn *squared* because induc-

using the pot-core winding tables

Assume the required inductance, L_X, is 150 mH. A ferroxcube pot core, 1811PA100 is to be used. Find the number of turns required, and the largest usable wire size.

1. Number of turns $= \frac{L_X}{A_L} \times 1000 = \frac{150}{100}$

$\times 1000 = 1225$ turns

2. Winding area of bobbin of 0.030 square inch (see table 5).

3. Turns per square inch: $\frac{1225}{.030} = 40{,}800$

4. From table 6, 39 AWG, heavy-Formvar insulation, has 53,855 turns per square inch, thus can be used to wind the 150-mH inductor. Assume a 22-mm core, Ferroxcube 2213P-A250 is wound with 40 AWG single Formvar. Calculate inductance when bobbin is fully wound.

1. Winding area for bobbin is 0.047 square inch (see table 5).

2. Turns per square inch for 40 AWG single Formvar is 82,180 (see table 6).

3. Winding factor of 90%: (82,190 X 90%) = 74,000 turns per square inch.

4. Number of turns: (74,000 X 0.047) = 3478.

5. Inductance is $\mu_e L_o$ mH (see table 5 for values). Therefore: (97.6) X (2.50 X 10^{-6}) X (3478 turns) = 2940 mH.

table 7. Abbreviated pot-core data for Ferroxcube cores. This information is used with the wire-winding data in table 6.

core diameter	pot core part no.	available core material 3B5	3D3	3H1	induct. (m h)/1000N)	μ_e	winding area (sq. in.) single section bobbin	LO (mHO)	accessories Bobbins	Hardware
	1408P-A40*	-	X	-	40	24				
14 mm	1408P-A60*	X	X	X	60	36	0.0158	$1.66N^2 x 10^{-6}$	1408 F1D	1408H
	1408P-A100*	X	X	X	100	60			1408 F2D	
	1408P-A160*	X	-	X	160	96				
	1811P-A40*	-	X	-	40	18				
	1811P-A60*	X	X	X	60	27			1811 F1D	1811H
18 mm	1811P-A100*	X	X	X	100	45	0.030	$2.19N^2 x 10^{-6}$	1811 F2D	
	1811P-A160*	X	X	X	160	73			1811 F3D	
	1811P-A250*	X	-	X	250	114				
	2213P-A60*	-	X	-	60	23.4				
	2213P-A100*	X	X	X	100	39				
22 mm	2213P-A160*	X	X	X	160	62.5			2213 F1D	
	2213P-A250*	X	-	X	250	97.6	0.047	$2.50N^2 x 10^{-6}$	2213 F2D	2213H
	2213P-A400*	X	-	X	400	156			2213 F3D	
	2213P-A600*	X	-	X	600	234				
	2616P-A100*	-	X	-	100	31				
	2616P-A160*	X	X	X	160	49				
26 mm	2616P-A250*	X	-	X	250	77			2616 F1D	
	2616P-A400*	X	-	X	400	123	0.067	$3.25N^2 x 10^{-6}$	2616 F2D	2616H
	2616P-A600*	X	-	X	600	185			2616 F3D	

*Add material designation to complete part number

tance increases as the square of coil turns. The AL number is almost always printed on the flat end of a pot core and is easy to find. If the core has no air gap it is usually marked OL.

As an example of using the AL number assume a Siemens core of N22 material; 18 X 11 mm with an AL number of 160. With 100 turns of wire on it the expected inductance will be:

$$L = (AL)\,T^2 = (160\ nH)\,(100T)^2$$
$$= 1.6 \times 10^6\ nH$$
$$= 1600\ \mu H \text{ or } 1.6\ mH$$

The size of the wire should be chosen to fill the bobbin, and charts are available to help choose proper wire size. Typical charts are shown in **tables 7** and **8.** These charts are for Ferroxcube pot cores, but since pot cores come in standard sizes they can be used approximately for other brands. (Siemens has a chart for metric wire sizes which would be of interest to European amateurs.)

There are a number of different ferrites from which pot cores can be used. Each manufacturer has his own designation for these and a recommended frequency range for each. Ferrites are made in this country by Indiana General, Stackpole, Allen Bradley, Ferronics and Arnold Engineering. Foreign manufacturers that market in the U. S. are Siemens, Ferroxcube (Phillips), Nippon Electric and TDK. Since each company has its own set of materials and designations, it is a bit hard to present a list of what type is best for a given frequency.

broadband rf transformers

Until ferrite and high-frequency powdered-iron cores became available there was no such thing as a broadband rf transformer. Now, thanks to these materials, they are widely used from below hf to above vhf. These broadband transformers use closed magnetic structures such as toroids, non-gapped pot cores and

table 8. Wire-winding data shows maximum number of turns of various wire sizes for the pot cores shown in table 5. Since pot cores come in standard sizes this data may be applied approximately to *all brands. This information* is based on exact layer winding. Normally 90% to 95% of these values are used, depending on whether the coil is random or layer wound.

wire size AWG	diameter	cross-sectional area circular mils	square inches	turns per sq inch hf wire	sf wire	resistance per 1000 ft
15	.0571	3260	256 10^{-5}	259	275	3.18
16	.0508	2580	203 10^{-5}	327	346	4.02
17	.0453	2050	161 10^{-5}	407	432	5.05
18	.0403	1620	128 10^{-5}	509	544	6.39
19	.0359	1290	101 10^{-5}	634	679	8.05
20	.0320	1020	804 10^{-6}	794	854	10.7
21	.0285	812	638 10^{-6}	989	1063	12.8
22	.0253	640	503 10^{-6}	1238	1343	16.2
23	.0226	511	401 10^{-6}	1532	1677	20.3
24	.0201	404	317 10^{-6}	1893	2094	25.7
25	.0179	320	252 10^{-6}	2351	2632	32.4
26	.0159	253	199 10^{-6}	2932	3326	41.0
27	.0142	202	158 10^{-6}	3711	4112	51.4
28	.0126	159	125 10^{-6}	4581	5213	65.3
29	.0113	128	100 10^{-6}	5621	6383	81.2
30	.0100	100	785 10^{-7}	7060	8145	104
31	.0089	79.2	622 10^{-7}	8455	10,097	131
32	.0080	64.0	503 10^{-7}	10,526	12,270	162
33	.0071	50.4	396 20^{-7}	13,148	15,615	206
34	.0063	39.7	312 10^{-7}	16,889	19,654	261
35	.0056	31.4	246 10^{-7}	21,163	25,531	331
36	.0050	25.0	196 10^{-7}	26,389	31,405	415
37	.0045	20.2	159 10^{-7}	31,405	39,570	512
38	.0040	16.0	126 10^{-7}	39,567	49,070	648
39	.0035	12.2	962 10^{-8}	53,855	65,790	847
40	.0031	9.61	755 10^{-8}	65,790	82,180	1080
41	.0028	7.84	616 10^{-8}	-	98,856	1320
42	.0025	6.25	491 10^{-8}	-	121,174	1660
43	.0022	4.84	380 10^{-8}	-	158,246	2140
44	.0020	4.00	314 10^{-8}	-	205,517	2590
45	.0018	3.24	254 10^{-8}	-	249,855	3200
46	.0016	2.56	201 10^{-8}	-	310,205	4050

note: hf is heavy Formvar insulation; sf if single Formvar.

multi-aperture cores. The amateur radio literature has a number of references on using toroids as balance-to-unbalance transformers (to match 50-ohm coax to balanced antennas).[7,8,9] Most of these references are derived from an article in the *Proceedings of the IRE.*[10] Balun-type transformers have become so popular that Amidon Associates offers the necessary toroid cores and wire in a balun-kit. The references show how to build 1:1 and 4:1 transformers (either balanced-to-unbalanced or unbalanced-to-unbalanced).

By using high-frequency ferrite pot cores, North Hills has rf transformers that will match 50- or 75-ohm coax to balanced impedances from 50 to 800 ohms. These transformers are apparently more difficult to build than the 1:1 or 4:1 types; they are probably adjusted at the factory with time-domain reflectometry (TDR). Reference 10 gives some details on optimizing bandwidth using TDR techniques. In using the North Hills transformers I found that a 50-to-200-ohm unit will not function well as a 75-to-300-ohm transformer, and so on. This is because the bifilar winding apparently acts as a *transmission line* which shouldn't be mismatched.

Broadband rf transformers are now available from at least four firms, including North Hills, Vari-L, Relcom and Vanguard in a variety of ratios. North Hills even has one that will take 1000 watts.

The broadband rf transformer has made a number of new devices possible. Probably the most important of these is the double-balanced hot-carrier diode modulator. These wonderful devices are available commercially from a number of firms. They are the nearly perfect mixer that was wanting for so many years. References 11, 12 and 13 cover some of the details and use of these mixers, and reference 4 shows how they can be built at home.

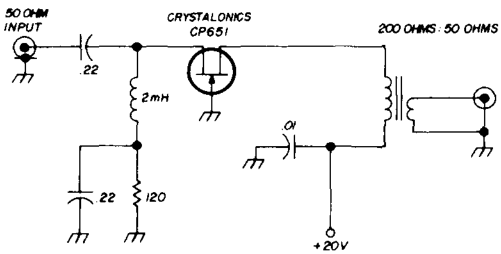


fig. 11. Basic circuit of broadband fet rf preamplifier used in Comdel HDR101. Bandwidth of unit is 0.5 to 40 MHz, voltage gain is 9 dB, noise figure is 2.5 dB, dynamic range is 140 dB.

Comdel, Inc.,* is using broadband rf transformers and fets to build a very fine high-frequency preamplifier. The Comdel HDR-101 is nearly perfect for improving sensitivity of communications receivers with minimum decrease in maximum signal handling capacity.[14] A typical high-frequency communications receiver may have a noise figure of 12 dB; the Comdel preamp has a noise figure of 2.5 dB with 9-dB gain. The combination yields a receiver system having 9 dB more gain and a 5.5-dB noise figure. A general description of the Comdel circuit was published in references 15 and 16; it is shown in **fig. 11.** Since the output transformer can be handwound as described in reference 10 this circuit is within the realm of home construction. Care is necessary in choosing the input rfc. No doubt there are a number of subtle engineering tricks that contribute to the excellent performance of the Comdel unit, but the circuit of **fig. 11** can serve as a start for the serious experimenter.

An interesting circuit for a broadband push-push doubler using a North Hills 50-to-400-ohm unbalanced-to-balanced transformer* is shown in **fig. 12.** The circuit cancels the fundamental by *balance* and requires no filtering to produce more second harmonic than fundamental. While it is shown using a matched pair of fets, I obtained somewhat similar results with a selected pair of HEP802s chosen with nearly equal I_{dss}.

The 400-ohm balanced to 50-ohm ferrite unbalanced transformer used in **fig. 12** is also quite nice for adapting older hf receivers to newer 50-ohm systems. Most older hf receivers (such as my Hallicrafters S20R) have a 400-ohm balanced antenna input which was designed to match the Zepp and similar antennas of the era. If you're one of the fortunate few who have a large rhombic fed with 600- or 800-ohm open-wire line commercial broadband transformers are available that will readily adapt your antenna system to a 50-ohm unbalanced receiver.

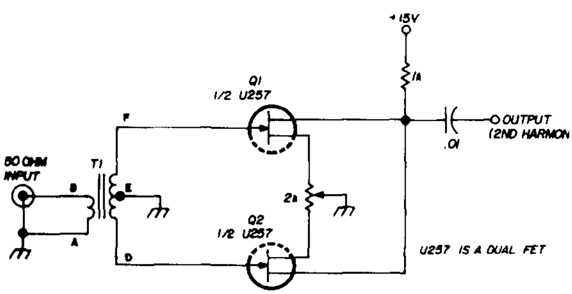


fig. 12. Broadband push-push doubler circuit. T1 is broadband 50-ohm-unbalanced to 400-ohm balanced transformer (North Hills 556026-336).*

*The author has a limited number of these transformers available to experimenters at $5.00 plus $0.50 for postage and packing. Write to Hank Olson, Post Office Box 339, Menlo Park, California 94025.

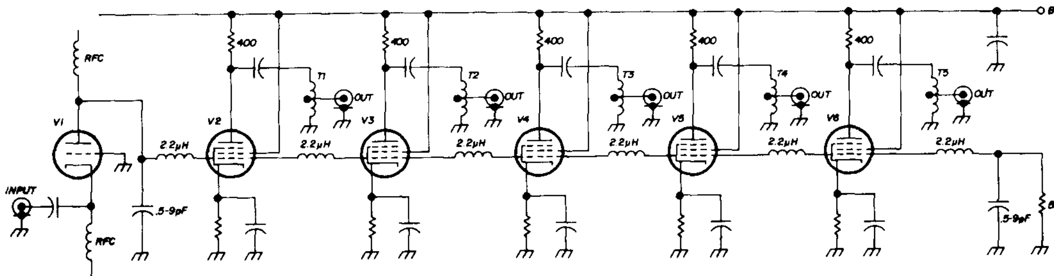


fig. 13. High-frequency multicoupler isolates receivers from antenna. Transformers are 200-ohm-to-50-ohm balanced-to-unbalanced, such as the North Hills 0502AA. Tube V1 is a high-transconductance triode (20,000 umho); other tubes are sharp-cutoff pentodes.

By combining a distributed amplifier with a broadband ferrite transformer it is a fairly simple matter to make a multicoupler as shown in **fig. 13;** it is used to connect up to five hf receivers to the same antenna. Each receiver is isolated from the others and may be used at any frequency in the hf band (assuming that the antenna is a broadband type such as a log-periodic). Note that the input capacitance of the pentodes and the 2.2-µH inductors from an artificial lumped-constant 500-ohm transmission line – this is why the input is broadband. This vacuum-tube design is obsolete in the semiconductor age but modification to fets should be fairly straightforward.

There are numerous uses for ferrite and powdered-iron cores in measurement equipment. Doug DeMaw's low-power directional power meter is a good example.[17] Another good antenna-measuring device uses a two-hole ferrite shielding bead in a bridge.[18] This simple bridge can be built with a two-hole ferrite bead available from W6KZK.

summary

High-frequency ferrites and powdered iron enable us to use techniques at higher frequencies which formerly were restricted to audio and power frequencies. If you can think of a magnetic component that is used at audio, the chances are quite good that the same technique can be applied at hf or vhf with the cores that are currently on the market.

*The ferrite core with windings, as described in reference 18, is available for $.50 from Swan Antenna Company, Post Office Box 1122, Stockton, California 95201.

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ham radio

customizing the fm control head

Modifications to improve performance of older mobile fm sets

Vern Epp, VE7ABK, 203 View Street, Nelson, B. C., Canada

Many two-meter fm enthusiasts can't afford the latest Motrac or Motran equipment for mobile operation and must be content with older offerings. Many older vibrator-powered mobile sets are available at reasonable prices but have certain disadvantages.

Some older sets have a frequency selection of four channels; however most are limited to one or two channels. Also, most older sets are trunk-mounted, which requires a control head. These heads aren't too attractive, especially when used in late-model cars. Furthermore, when it's desired to add other circuits, these heads can't be used unless they're large.

In this article I've described some modifications that will improve a typical two-meter mobile fm set – the RCA Carfone. These modifications are adaptable to other sets with a little ingenuity.

The original Carfone remote head was reinstalled in a new enclosure for enhanced appearance. Other features were also added to make this equipment competitive with late-model mobiles:

1. Modification from 2- to 5-channel operation.

2. Modification for a dynamic microphone.

3. Addition of a dial encoder for repeater and auto patch.

4. Adaptability for channel scan (which will be added later).

multichannel modifications

A mobile fm set can be modified in many ways for multichannel operation. If space is a consideration, it is advantageous to remotely locate the transmit and receive crystal oscillators. The circuit of **fig. 1** was added to the control head of my set to increase frequency coverage. (Interested readers may wish to read the article in which this circuit first appeared.)[1]

Referring to **fig. 1,** a multichannel crystal oscillator and emitter follower provide signal inputs to the trunk-mounted set via RG-58/U coax cable. Selector switches for transmit and receive modes are independent, so any combination of frequencies within the limits of the circuit is possible. This is especially desirable because many frequencies are used on two meters for repeaters with simplex operation. Printed circuit boards are available for those wishing to make this conversion.*

Two circuit boards are required, one for the transmit and one for the receive channel. The transmit-channel oscillator supplied sufficient drive to produce the

*Write Sam Craig, W2ACM, 5812 Tilton Road, East Syracuse, New York 13057.

same output as that from the original oscillator in my unit. However, the injection signal from the receiver board was rather low, so I included a resonant circuit consisting of a slug-tuned inductor and parallel capacitor tuned to the crystal frequency. This circuit was installed between the receiver-board output and the 0.01-μF coupling capacitor (**fig. 1**). The signal was then routed via RG-58/U cable to the set in the car trunk.

If your mobile set has two channels, with this addition you'll have five channels. The remote unit supplies four channels, and a fifth is obtained by leaving one set of crystals in the trunk-mounted unit.

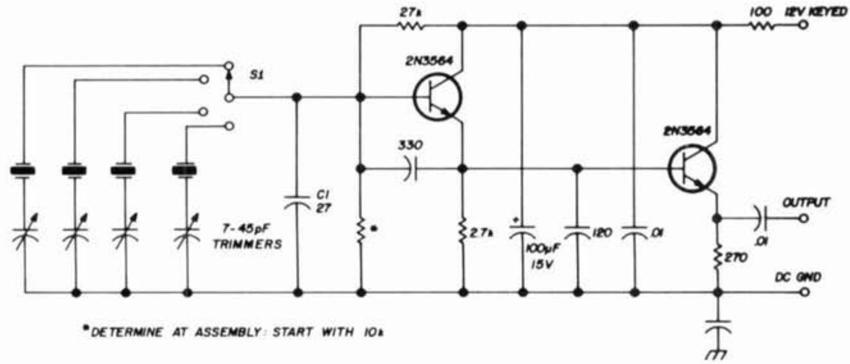
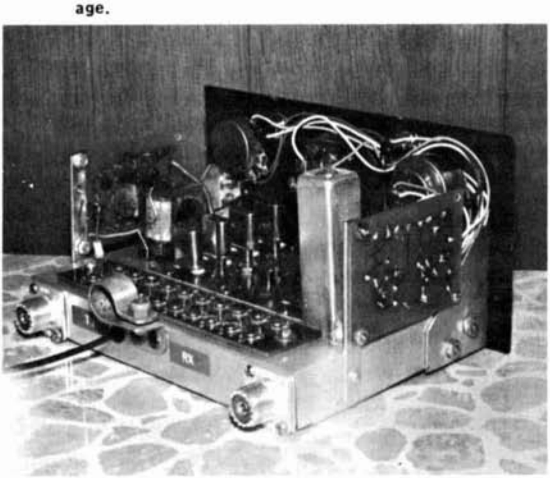


fig. 1. Remote oscillator circuit for multifrequency operation. Two circuit boards are required. Receive board is fed directly from 12 Vdc at on-off switch. Transmit board is fed by a keyed 12 Vdc source. Output of each is fed via RG-58/U coax to trunk-mounted set between grid and ground of original oscillators.

Rear view of the RCA Carfone showing addition of transmit and receive oscillator boards for extended frequency coverage.



microphone modification

Most older fm sets use a carbon mike. Its audio quality is fair but not the best. The modern (medium- to high-priced) fm mobile units are designed to use a dynamic mike that has a built-in preamplifier.

My unit uses a Motorola CTMN6019A mike, which requires approximately 4 volts negative to drive the built-in preamp (**fig. 2**). Some mikes, like the Shure 405T, operate from a positive-supply voltage, which is readily available from the B+ supply through a voltage divider and filter. The improvement in audio quality is remarkable, and the new microphone is much more attractive next to the new control head.

dial and encoder

The telephone dial, which is mounted on the front panel of the modified control head, pulses the tone encoder. My encoder unit, shown in **fig. 3,** oscillates at about 2.6 kHz. The oscillation frequency is easily changed by selection of the capacitor across the toroid transformer primary. Any good npn transistor can be used. Component values aren't at all critical. The encoder frequency will have to fit the requirements of your area.

This circuit can be used for auto patch

control with a repeater station that includes this feature. Auto patch is becoming quite popular in the U. S. as well as in Canada. It allows the mobile fm operator to communicate via landline telephone circuits and is sanctioned by "Ma Bell."[2]

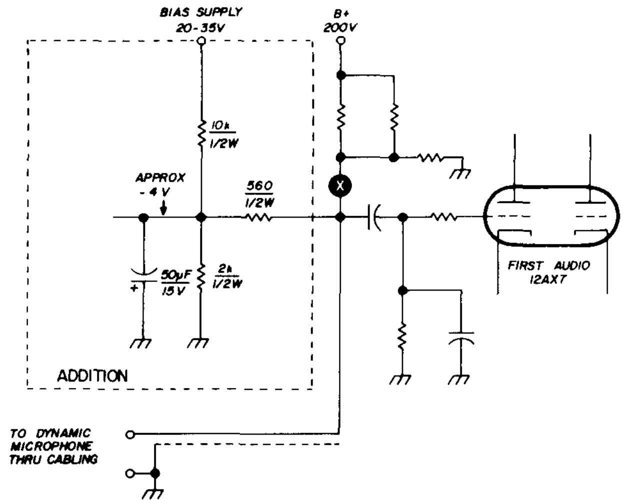


fig. 2. Modifications for converting the RCA Carfone mobile to a dynamic microphone input. Break circuit at point X.

channel scan

This is a monitoring system that permits you to keep track of more than one channel at a time, while automatically locking onto a transmitting channel. Most systems use a ring counter (one for each channel) triggered by a unijunction relaxation oscillator. The UJT, in turn, is operated by the noise rectifier of the mobile unit. The control head as described is not equipped for this feature but is compatible with such a modification.

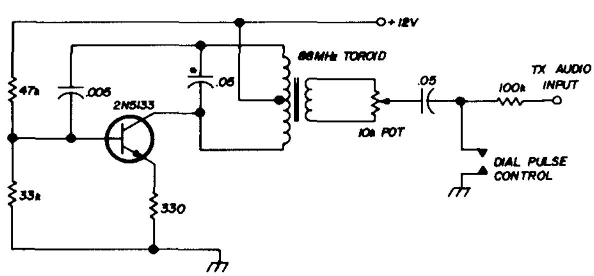


fig. 3. Dial encoder oscillator using an 88-mH toroid and junk-box parts. Capacitor marked with asterisk determines frequency.

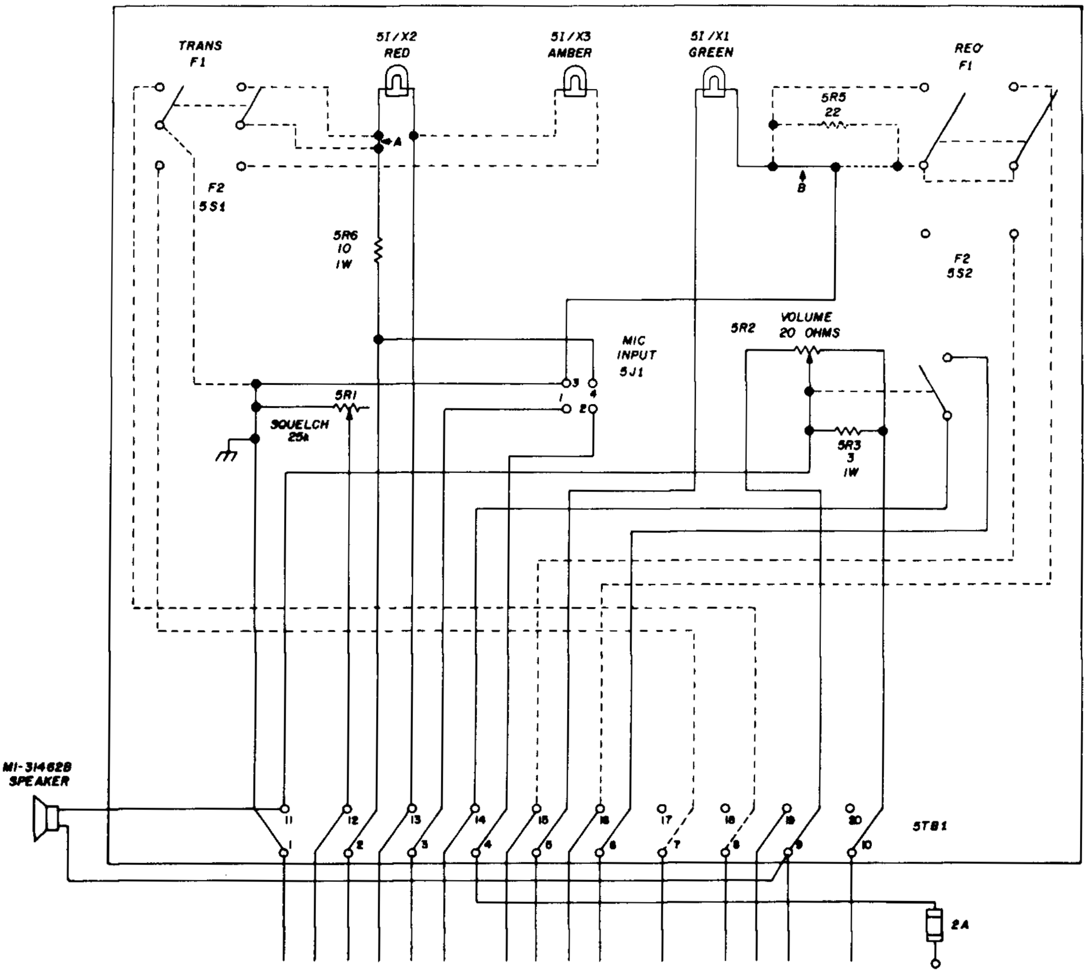
closing note

Mobile fm operation is a very popular part of ham radio, and the number of converts to this communication mode is increasing at a tremendous rate. The benefits of mobile fm over CB channels are obvious. Almost every metropolitan area has one or more amateur fm repeater stations that receive the mobile signal and retransmit it at increased power, thus allowing even the most modest mobile signal to be "top dog" on the frequency.

Fm equipment is reliable and generally trouble-free. When it is necessary to service fm equipment, you won't have much trouble getting your set back into operation because of the commonality of circuits – you can usually find someone who is familiar with your particular equipment.

your particular requirements. All circuits shown here have been tried and proven.

The improved appearance of the modified control head will keep the wife happy, and the dial will keep the kids



Circuit of original control head which was installed in the new control box.

Controls are simple and straight-forward, consisting of an on-off-volume control, squelch control, and push-to-talk microphone. Antennas are physically small and easy to install and tune.

I have described a number of ways to customize an older mobile two-meter fm installation. The extent of your modernization work will, of course, depend on occupied on those long trips (but be sure the equipment is switched off!).

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ham radio

power, voltage and impedance nomograph

These graphs permit rapid conversion from one unit of measurement to another — they are particularly useful when using an oscilloscope for waveform analysis

Walter E. Pfiester, Jr., W2TQK, Box 85, 1 Skadden Terrace, Tully, New York 13159

When working with various electronic systems it's often necessary to think in terms of power, voltage, impedance and dBm, and to move rapidly from one unit of measurement to another. Rather than making a calculation each time you change from one unit to another, it is much easier to use the graphs in **figs. 1** and **2.** These graphs are an analysis of power vs voltage as a function of impedance.

The chart in **fig. 1** covers power levels from 1 milliwatt to 1 watt, while the graph in **fig 2** covers the range from 1 watt to 1 kilowatt. The power range in dB above a milliwatt, or dBm, is shown on the right hand side of each chart.

These graphs are extremely useful when using an oscilloscope for waveform analysis, and direct conversion to power level is necessary. They are also useful in the design and calibration of rf voltmeters and wattmeters.

how to use them

When laying out these graphs one of the prime considerations was to make them easy to use. All you have to do is enter the graph with the known quantity and continue to the appropriate impedance line; read the unknown value on the opposite axis of the graph. For example, what power level is represented by 10 volts peak-to-peak across a 50-ohm line? Enter the chart at the 10-volt point on the lower axis, project upward to the 50-ohm impedance scale, then to the left to 250 milliwatts. Note that this corresponds to 24 dBm on the right-hand side of the chart.

Although the impedance curves on the face of the chart are limited to the most common transmission-line impedances, the power and voltage curves are not restricted to these impedances. The impedance ruler at the top of each graph may be used to construct other impedance lines; simply draw a straight line

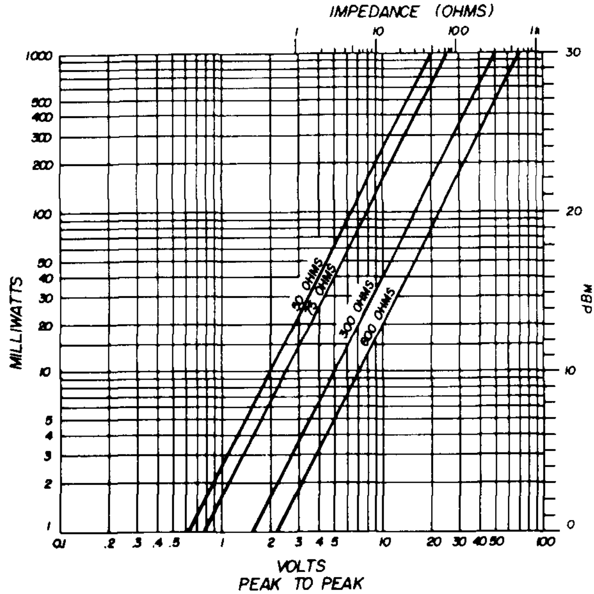


fig. 1. Power, voltage and impedance nomograph for power levels from 1 milliwatt to 1 watt.

through the appropriate point on the impedance ruler, keeping the new impedance line parallel to those already plotted.

The choice of peak-to-peak volts on the horizontal scale is based on the use of an oscilloscope as the primary measuring tool. If you wish, this axis can be recalibrated in any convenient terms that relate directly to peak-to-peak voltage. For example, for peak voltage, divide by 2; for rms voltage, divide the scale by 2.8.

I would appreciate hearing from any readers who find an unusual application for these graphs.

ham radio

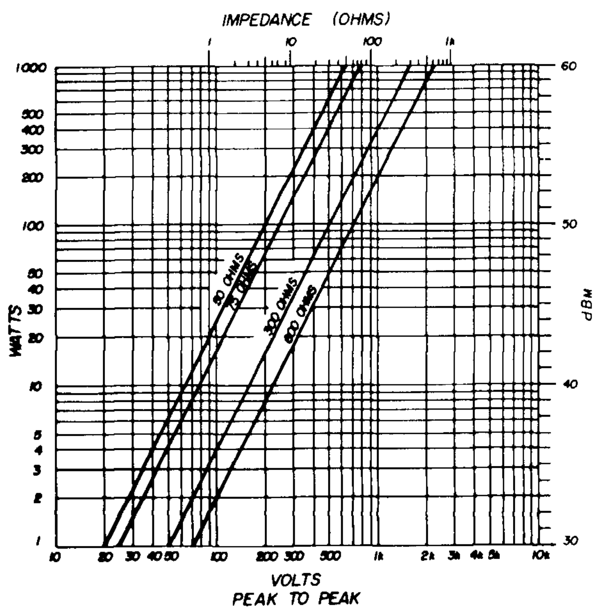
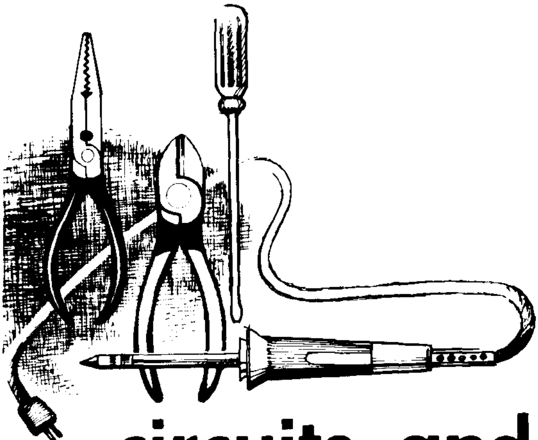


fig. 2. Power, voltage and impedance nomograph for power levels from 1 watt to 1 kilowatt.



circuits and techniques

ed noll, W3FQJ

power fets

Power field-effect transistors have now been developed and are available. Is it possible that power fets can be produced that will give bipolars and vacuum tubes a run for their money? Per watt cost remains high but is dropping. There is hope!

What are some of the advantages for power fets in high-frequency power-amplifier applications? Low input impedance and secondary breakdown problems, two headaches of bipolar transistors, are absent; interstage coupling and matching are easier. As an extra bonus there is low intermodulation distortion in linear rf amplification, less troublesome output circuit design and no thermal runaway. In addition, power fets are capable of high voltage operation so less current is required for a given dc input and rf output power.

fet characteristics

There are a number of important notations and parameters important to the operation of a field-effect transistor as a high-frequency power amplifier. These are listed in **table 1.**

In a field-effect transistor there is an essentially constant fixed relationship between pinch-off voltage, Vp, saturation current, I_{DSS}, and transconductance, g_{fs}. As gate bias is increased, drain current decreases in a square-law manner. In fact, the drain current changes between zero gate bias and pinch-off gate voltage in accordance with the following ratio:[1]

$$\frac{I_D}{I_{DSS}} = \left(\frac{V_P - V_{GS}}{V_P}\right)^2$$

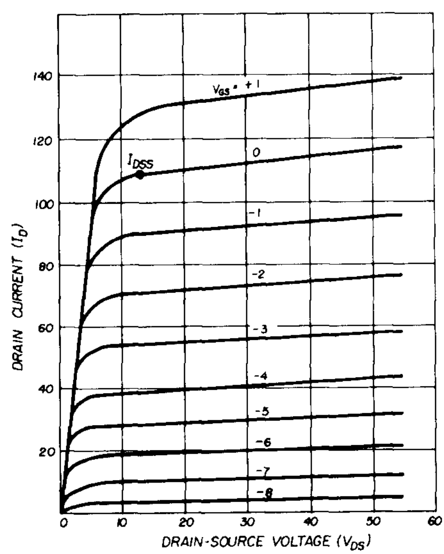


fig. 1. Typical field-effect transistor operating characteristics.

table 1. Field-effect transistor parameters.

I_D	dc component of drain current
i_d	instantaneous drain current
i_D	instantaneous total drain current (dc and ac drain current components)
I_{DSS}	drain current at zero gate voltage (note 1)
V_{DD}	drain supply voltage
V_{DS}	dc drain voltage
v_{ds}	instantaneous drain voltage
V_{GS}	gate-source voltage
V_P	gate-source pinch-off voltage (note 2)
v_{GS}	instantaneous total gate-source voltage (ac and dc components)
V_{PB} or V_{bias}	cut-off bias voltage
g_{fs}	common-source configuration forward transconductance
C_{iss}	common-source configuration input capacitance

note 1: I_{DSS} is usually measured at a low drain-source voltage, V_{DS}, corresponding to the beginning of the constant-current saturation region of the zero-bias curve, fig. 1.

note 2: The pinch-off voltage, V_P, is that gate-bias voltage, V_{GS}, at which the drain current is reduced to practically zero for a specified drain voltage, V_{DS}. This drain voltage is sometimes the one specified for the measurement of I_{DSS}.

From this expression you can develop the fundamental large-signal equations of a power fet.

class-AB linear operation

Above the I_{DSS} point on the zero bias curve (above pinchoff on all bias curves) the fet has a square-law transfer characteristic. If operation is confined to this range, intermodulation distortion components of any objectionable magnitude are not developed. Harmonic components do appear but these are suppressed in the output resonant circuit (**fig. 2**).

Efficient operation and maximum linear output occur when the instantaneous peak drain current, i_D, reaches I_{DSS} at the positive crest of the input signal, and signal swing occurs over the entire range of the square-law region. Minimum load is placed on the signal source when *the positive crest of maximum input* signal swings no more positive than the zero gate voltage.

class-c operation

More output and higher efficiency can be obtained from the class-C mode. This can take advantage of greater drain voltage and drain current swings. Higher gate bias is used, and the conduction angle is approximately 120°.

However, somewhat more driving power is needed in class C. Input loading is light, especially when gate-channel conduction is avoided by not permitting the crest of the input rf wave to swing above zero gate bias.

In the practical planning of an fet rf power amplifier there are three equations of importance. These determine the required gate bias, zero-signal drain current and load impedance (see **table 2**).

input circuit conditions

The load placed on the preceding stage by the input circuit is determined by the

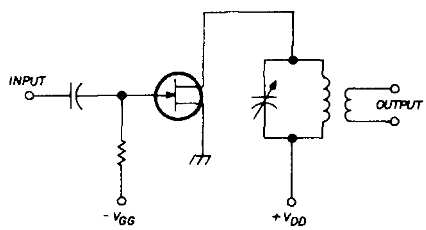


fig. 2. Basic fet tuned amplifier.

gate resistance, r_g and input capacitance, C_{iss}. Gate resistance is similar to the base resistance of a bipolar transistor and is determined by the resistivity of the semiconductor material; it acts in series with the common-source input capacitance. Since this capacitance is very low, input impedance is very high. Input impedance decreases with frequency because the reactance of C_{iss} decreases.

To summarize, most efficient opera*tion without gate current occurs when*

table 2. Design equations for fet rf power amplifiers.

Bias for class-AB linear	$V_{BIAS} = V_P/2$
Bias for class-C	$V_{BIAS} = V_P$
Load resistance	
Class-AB	$R_L = \frac{V_{DD} + (-V_P)}{I_{DSS} - I_D}$
Class-C	$R_L = \frac{V_{DD} + (-V_P)}{I_{DSS}}$
Dc drain current	
Class-AB	$I_D = \frac{I_{DSS}}{4}$
Class-C	$I_D = 0$

the peak of the rf drive signal reaches an instantaneous gate voltage that produces a drain current equal to I_{DSS}. The operation of a class-AB linear amplifier is maintained on the square-law portion of the transfer characteristic. To do so the operating bias must be set at a value of $V_P/2$. Based on the square-law response the static dc drain current for zero signal becomes $I_{DSS}/4$.

In class-C operation the conduction angle can be dropped to 120° and may swing off the square-law portion of the curve. In this case operating bias is set to the pinch-off value, V_P. Higher output is obtained and more driving power is needed. The zero-signal drain current becomes zero because of the pinch-off bias; drain current swings between zero and the I_{DSS} value.

Specifications for various high-frequency power field-effect transistors are given in **table 3.** Practical operating conditions for class-AB linear and class-C amplifiers can be calculated with the simple formulas shown in **table 2.**

Power fets are presently quite expensive, but useful experience can be obtained in the milliwatt level with less expensive types such as the Siliconix U-183 and Motorola HEP-801 and HEP-802. These devices cannot be classified as power fets but they permit operation up to 100 milliwatts.

A practical fixed-bias amplifier is shown in **fig. 3.** Note its similarity to vacuum-tube circuitry. Input and output resonant circuits are used. Gate neutralization is often needed because of the high input impedance of the stage. Inasmuch as the feedback capacitance Crss is reasonably constant, neutralization is usually possible with a *fixed* neutralizing capacitor. Typical gain on the 10-meter band is 20 dB in class AB and 25 dB in class C.

self-biasing

Power field-effect transistors can be operated as self-biased amplifiers. In this case the positive sweep of the drive signal is adjusted so that the gate-channel junction is forward biased at the peak of the gate input signal. Electron charges then flow instantaneously from the channel to the gate, and a negative dc bias can be developed with a gate-input resistor-capacitor network in **fig. 4.**

Input impedance is lowered with this system, and more driving power is required to overcome the gate circuit losses. However, you can dispense with an external gate-bias source. Although interstage coupling and matching are somewhat more troublesome than for the no-gate-current mode of operation, the problems are less difficult than those encountered in a bipolar amplifier of comparable power.

power oscillator

Power field-effect transistors perform

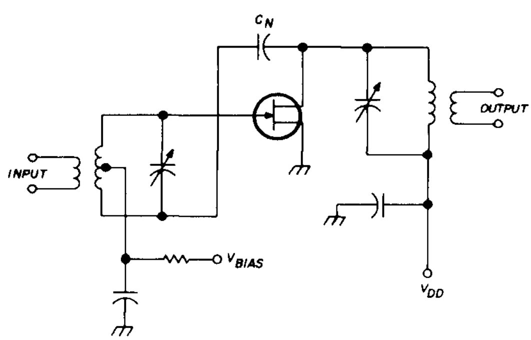


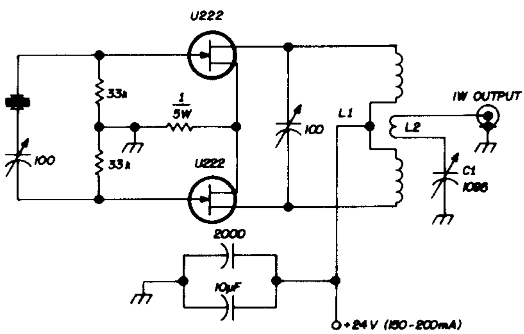
fig. 3. Fet amplifier with fixed bias.

table 3. Operating parameters of currently available power fets.

	Siliconix				Crystalonics			
	U183	U222	U244	U266	CP653	CP652	CP651	CP650
Gate-drain Gate-source Maximum Voltage	25	50	25	G-D 150 G-S 20	20	20	20	25
I_{DSS} (mA)	20	150	600	200	60	100	300	600
V_P	-8	-8	-8	-12	-5	-5	-5	-5
Maximum Drain Current (mA)	—	—	900	500	600	600	600	1200
Maximum Gate Current (mA)	10	25	—	—	—	—	—	—
Device Dissipation Ambient 25°C (W)	200	800	—	—	—	—	—	—
Device Dissipation case 25°C (W)	—	3	10	10	8	8	8	8
g_{fs}	5000	30000	150k	30000	6000	10000	10000	15000
C_{iss}(pF)	8	20	35	28	20	20	20	20
C_{rss} (pF)	4	4	15	16	—	—	—	—
Gate-source Breakdown Voltage	-25	-50	-25	-20	-20	-20	-20	-25
Power Output (W)	—	0.5	10	10	—	—	—	—

well as self-biased power oscillators. The high gate impedance has a minimum loading effect and oscillation starts easily in simple circuits. All the various crystal variations can be used — Pierce, Miller, Colpitts and modified Pierce — with a tuned output circuit. The simple Miller circuit works well. This can be a troublesome bipolar circuit at higher oscillator power levels. Furthermore, fets take off well in the push-pull circuits so popular in early vacuum-tube practice.

A practical push-pull circuit for 160-meters is shown in **fig. 5**. Power output of better than 1 watt can be obtained from this circuit using the component values shown. Inasmuch as cw operation is usually confined to a rather narrow span of frequencies on 160, the series variable in the gate circuit permits a helpful frequency spread. Low-cost U-183s and HEP-801s operate in the same circuit.



C1 1095 pF (three-gang broadcast variable)

L1 60 turns no. 26 enameled, closewound on 1¼" form, center-tapped. Leave space for L2 at center

L2 15 turns no. 26 enameled, closewound between two windings of L1

fig. 5. Push-pull fet crystal oscillator for 160 meters.

wideband amplifier

Power fets do well as broadband amplifiers. The example in **fig. 6** uses a Crystalonics CP651. Gain is 10 dB from 500 kHz to 40 MHz. Maximum input signal is 3 volts peak-to-peak across 50 ohms. A voltage gain of 10 dB builds this up to 9.5 volts across 50 ohms. Output power can be several hundred milliwatts.

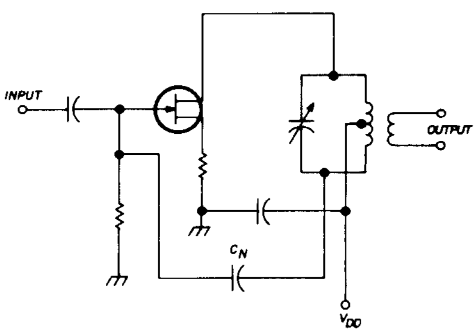


fig. 4. Signal biased fet amplifier.

fet harmonic generator

The high gate impedance of the field-effect transistor results in minimum crystal loading and an opportunity to emphasize harmonic output from a single stage. Such a circuit for obtaining good harmonic output was presented in *Electronics,*[2] **fig. 7.** The circuit reminds me of the old-fashioned tri-tet vacuum-tube crystal oscillator.

Fundamental oscillations are determined primarily by components in the gate-source circuit. The source circuit is tuned to a frequency somewhat lower than the crystal frequency (about 0.7 f_X). The resonant frequency must compensate for the influence of the gate-source capacitance of the fet.

The drain circuit must be set to the desired harmonic. Oldtimers will recall from past vacuum-tube experiments that this circuit produced a good odd-harmonic output and was often used as a tripler — and occasionally as a five-times crystal generator. Second and forth harmonic outputs are acceptable too.

Such a multiplier circuit is attractive for QRP operation because a 40-meter crystal will provide a strong 15-meter output. Forty-meter output can be obtained by tuning the drain circuit to the 7-MHz frequency and shorting out the source tank circuit. This circuit is also attractive for multiplying into the 2- and 6-meter bands.

vhf double sideband

Have we overlooked an economical means of transmitting sideband on the vhf bands? There are few amateurs with-

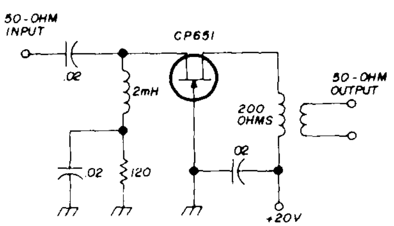


fig. 6. Wideband power amplifier. Response is flat from 500 kHz to 40 MHz.

appendix

The fundamental equation is

$$\frac{I_D}{I_{DSS}} = \left(\frac{V_P - V_{GS}}{V_P}\right)^2 \qquad (1)$$

In operation, the instantaneous total drain current is

$$i_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2 \qquad (2)$$

However, by expansion the fundamental component for a tuned rf amplifier is

$$i_D = 2I_{DSS}\left(\frac{V_{GS}}{V_P}\right)^2 \qquad (3)$$

The practical equations of the fet power amplifier are developed from **eq. 3.**

If the instantaneous i_D is to reach I_{DSS} on crest, (ie., $i_D = I_{DSS}$),

$$1 = 2\frac{V_{GS}}{V_P}$$

$$V_{GS} = \frac{V_P}{2}$$

This relation estimates a practical value of cutoff bias. For linear operation and a conduction angle of 180° the gate cutoff bias should be $V_P/2$. This ensures the signal swing can occur over the square-law region, and peak gate signal voltage reaches only zero gate bias.

Based on square-law transfer and i_D(peak) = I_{DSS}, the dc static drain current at zero signal level is

$$I_D = \frac{I_{DSS}}{4}$$

As the gate voltage swings between $V_P/2$ and 0, a load impedance of proper value produces maximum output and highest efficiency. The required load is

$$R_L = \frac{V_{DD} + (-V_P)}{I_{DSS} - I_D}$$

In class-C operation, a 120° conduction angle is obtained with twice cut-off bias

$$V_{cut\text{-}off} = (V_{P/2}) \times 2 = V_P$$

Bias is now at pinch-off value, and zero-signal static drain current is zero (I_D - 0) required load resistance becomes

$$R_L = \frac{V_{DD} + (-V_P)}{I_{DSS} - 0}$$

out the means of receiving high-frequency sideband signals; connect simple converters ahead of these receivers and you are blessed with an excellent vhf sideband receiver.

The transmit mode is more of a problem, requiring a transverter or a multiplier-mixer chain. You must start out with a sideband signal, and not everyone has this facility, particularly those who do all their operating on vhf.

bands because it occupies no more space than an a-m signal.

The dsb signal can be created right on the transmit frequency. Any number of techniques can be used, including high-powered vacuum tubes in a balanced push-pull circuit. Modulation can occur at low power level directly at the output of a crystal or vfo-controlled multiplier.

As a matter of fact, there will probably be a gradual displacement of the multiplier chains now so common, particularly on 2 and 6 meters. Stable solid-state vfos can be designed for operation directly on these bands.

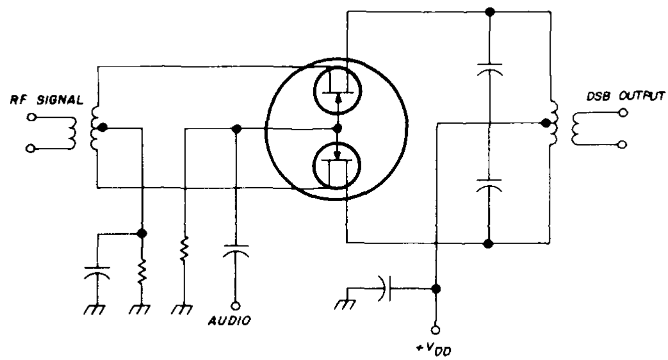


fig. 8. Dual-fet balanced modulator for double sideband generation. Capacitor C1 provides the carrier-balance adjustment.

The double-sideband technique provides an easy way of obtaining a sideband signal. In this mode of transmission the carrier is removed while both sidebands are transmitted. An ssb receiver is used for reception; either sideband can be received with appropriate setting of the receiver USB-LSB switch. A double-sideband signal isn't objectionable on the vhf

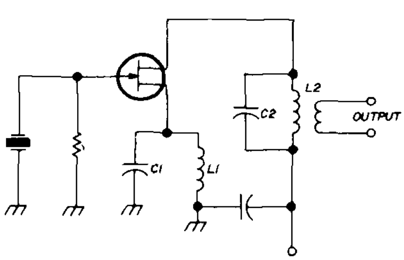


fig. 7. Harmonic crystal oscillator provides strong output at 2, 3, 4 and 5 times the crystal frequency. A HEP-802 works well in this circuit. C1 and L1 are tuned to the crystal frequency; C2 and L2 are tuned to the output harmonic.

There are any number of low cost crystal diodes that operate efficiently up to 500 MHz. These can be used in various balanced-modulator diode configurations. Field-effect transistors and integrated circuits are also available for this use. The dual-fet, **fig. 8,** has good possibility. The circuit is so simple and the components so few that good performance is almost a certainty. If you are a purist, this configuration can be connected in a double-balanced modulator as an ideal way of generating a phasing-type single-sideband signal. We'll dig into this one, too, a little later.

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1. Siliconix applications note, "High-Frequency Power Field-Effect Transistors."
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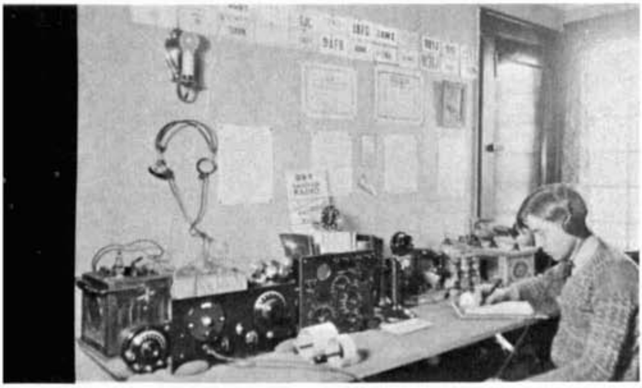


those were the days

An invitation to share some happy memories with an oldtime radioman

John D. Davies, K4NW, Box 188, Rockledge, Florida 32955

From time to time *ham radio* has presented articles on the early days of wireless and the work of some of the pioneers who have contributed to the art of radio communication. While the space devoted to these pieces might well have been used for more items on today's technical problems and their solutions, we at *ham radio* feel that an occasional digression into radio's past helps preserve the editorial balance we're trying to achieve – in short, a magazine with "something for everyone."

This article is dedicated to the old timers – a very substantial portion of the ham fraternity. Many are still active, even after fifty years or more. What's more important, many old timers have kept abreast of the rapidly changing technology in electronics and have made significant contributions to the state of the art. And that's a healthy sign.

For interested readers, a bibliography is included at the end of K4NW's old-time radio story. These are articles we've published over the years by another old timer who has kept up with the action – Ed Marriner, W6BLZ. **editor.**

Radio communication from 1920 through the early Thirties held a peculiar fascination for the public, perhaps because people then were less sophisticated than the present generation. The air of mystery surrounding early radio seemed to motivate even those with no knowledge of electricity into trying their hand at constructing a radio set. Some were content to replace their primitive sets with manufactured models as they became more numerous and as prices became more reasonable. Others, unable to resist the urge to experiment, continued to learn, to innovate, to improve; and so ham radio began to flourish.

Come with me for a few nostalgic moments and we'll look at some of the early hardware and ideas that formed the basis of today's electronics.

early equipment

If you were a teenager around the first half of the Twenties, surely you'll remember the Reinartz circuit; three-circuit tuners; honeycomb and bank-wound coils; Daven resistors; Radiola, Grebe, and Paragon receivers; and a host of other components and equipment. Remember the smell of shellac on homewound coils; the sound of chemical rectifiers bubbling inside Mason jars; VT1 and VT2 tubes; the whine of a correctly adjusted synchronous spark gap? – Ah, sweet memories!

Me? I started my radio career with a crystal set. The inductor was wound on a Quaker Oats box using no. 22 dcc wire. Then the insulation was carefully scraped off, and taps were soldered onto the wire for a switch. I didn't use a variable condenser – just switch points. The rest of the circuit consisted of a galena-and-catwhisker detector, a "phone condenser" of tinfoil and waxed paper sandwiched together, and earphones. This was around 1921 and '22. Soon thereafter this deluxe layout was followed by an "Arlington Loose Coupler" and a "Fada Crystal Detector."

publications

Early newspapers featured a "radio section" offering the latest do-it-yourself project – a reflex, neutrodyne, or similar receiver circuit (they all worked about the same) – together with the latest version of the popular "three-circuit tuner." All were accompanied by more or less authentic advice, depending on who happened to be the current "radio editor."

Radio magazines of the day were sometimes a wonder to behold. Those wishing to build equipment from the published circuits followed instructions to the letter. If the instructions called for double-cotton-covered wire, for example, you'd never dream of using single-cotton-covered wire – it was all that mysterious.

Many early radio magazines carried Q & A columns for aspiring radio constructors. Some of the questions and answers were interesting. A typical query, appearing in a 1923 edition of a popular mag, went like this:

"Q. What is the advantage of connecting the tube-filament rheostat in the negative wire of the 'A' battery circuit?"

The editor, who was somewhat of a diplomat and a little unsure of the answer himself, replied:

"A. Better results will be obtained if the rheostat is placed in the negative lead of the 'A' battery. This is particularly true of the UV-201A tube . . ."

A circuit then followed showing an elaborate switching arrangement that allowed the filament rheostat to be transferred between positive and negative leads of the filament supply. (The editor took no chances.)

The same blind faith went for antennas. If the article or book you were following said to use no. 14 7-strand copper, you wouldn't dare use no. 12 solid. Arguments were rife on the merits of four versus six parallel wires between the antenna spreaders. Some swore by cage antennas. After all, if your neighbor heard PWX (Havana) with a cage, what more proof did you need? Before long, though, some DX hound who finally at 3 a. m. snagged KFI in Los Angeles would claim that a 150-foot-long wire was superior to all spreader-type aerials. Who were you to question such a feat? Down

The operating corner of W2BKD's shack.

with the cage; up with the long wire. And so it went.

broadcast stations

In the early days, many experimenters were interested in receiving the radio broadcast stations that began to appear all over the world. There was, of course, KDKA in Pittsburgh; WOC in Davenport; Milton J. Cross in Aeolian Hall at WJZ. Then there were CZE, Mexico City; 2LO in London with Big Ben (live) tolling midnight to the tune of background music furnished by a dance band at Ciro's.

The "International Tests," held once a year, were highlights for the DX listener. American broadcast stations would shut down for a time so we could listen for European stations; while another night the Latin Americans would come through.

Then there were the corny jokes of the DX hounds: "I opened the window last night and got Chile;" "My wife was in the kitchen and I heard China;" "Are you Hungary? I'll Russia to the table and Fiji" – to name a few. Yes, those were the days!

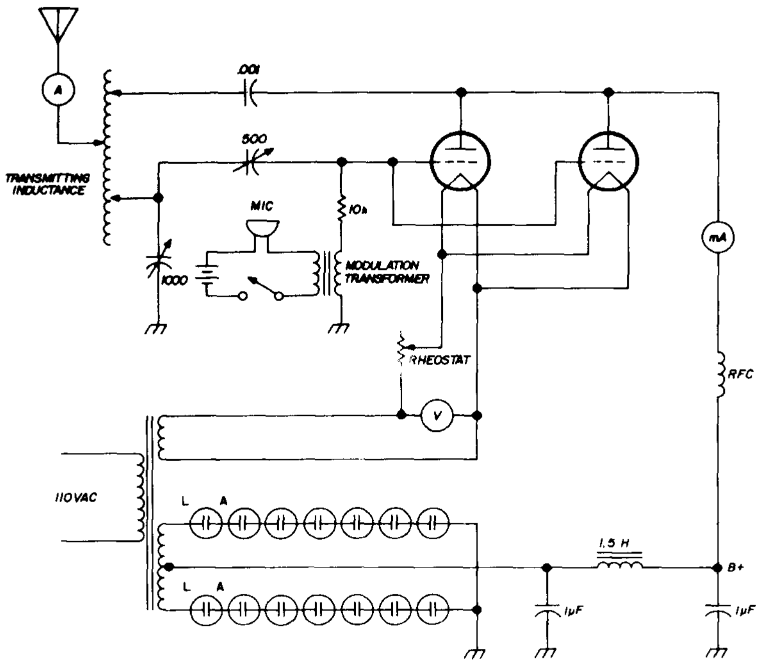


fig. 1. A 10-watt cw and phone transmitter popular during the early Twenties. Power was supplied to a Colpitts circuit by electrolytic rectifiers. "Very good results" were claimed for this "Hook-Up."

spark transmitters

I was a bit too young to be identified closely with spark, except for experimenting with a certain portion of Henry Ford's ignition system – but I knew spark was around. At frequent intervals a foreign ship would drop anchor in the Hudson and open up with what I understood to be, in ham terminology, an "Old Betsy." The operator would tear the air apart for a while then move on, to be replaced by another vessel with, perhaps, an old Federal arc transmitter whose sound was pure music compared to the spark transmitter.

the "short" waves

One day word got around that amateur radio operators had "spanned the Atlantic!" I didn't have a ticket then. I was still "bootlegging" across town with a Ford spark coil and wondering whether a hot pink spark was better than a cool blue one. But I started winding coils with fewer turns, and to this day I've never left that wonderful land "below 200 meters."

When I finally landed a ticket I tried to get my ac-powered oscillator somewhere near the 40-meter band. I listened

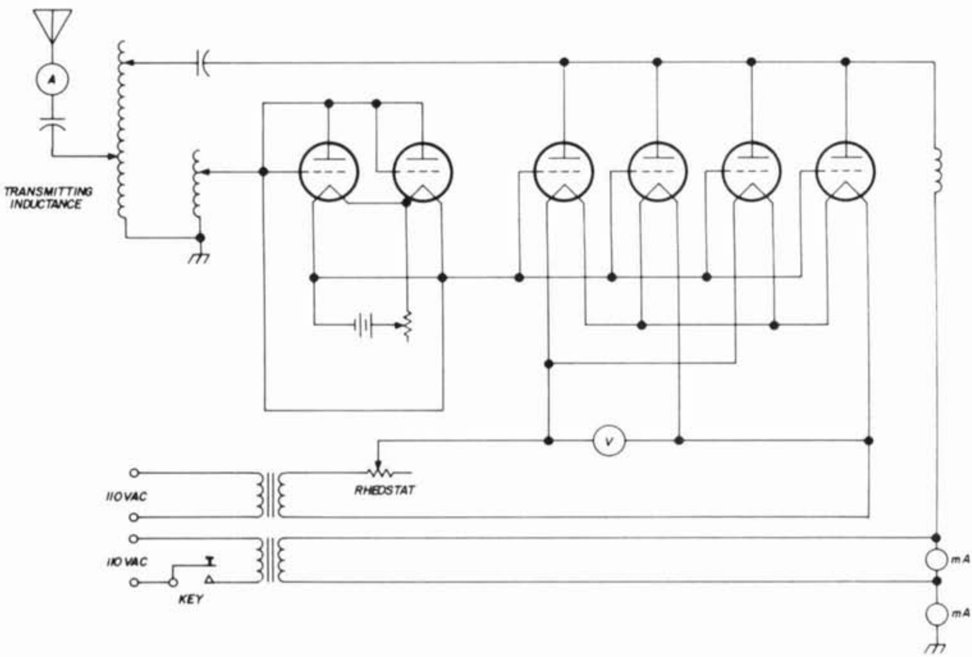


fig. 2. French station 8AB's transmitter, heard often in the U. S. during the Trans-Atlantic tests. Rig ran 1 kW input, using French 250-watters. Two keys were necessary "to allow the hot one to cool while the second was in operation."

Troubleshooting a "tough dog" (c. 1930).

for a CQ that first day, and finally there it was: NU1AD (NU was shortly replaced with W in U. S. amateur call signs).

I timidly clicked out NU1AD's call. In those days you didn't listen on your frequency; you "combed the band" for replies. Lo and behold: NU1AD answered! When I told him (C. S. Doe, Bellow Falls, Vermont) that he was my first contact, he calmly recounted how he'd worked across Boston harbor with a spark set in 1916 for *his* first radio contact. Nowadays I tell the young novices how I worked all the way from New York to Vermont in 1928 with 5 watts.

transmitters

The rig responsible for my first contact used a single 210 (UV-210, rated at

7-1/2 watts) in a Hartley circuit, fed by all the ac I could muster. Today it would make a first-rate jammer. The antenna was a voltage-fed Hertz, very popular at the time along with the Zepp.

Other equipment included an ancient running at around 15 or 20 watts. The plate would go from red to yellow if you made your dashes too long; but everybody knew this and didn't get unduly alarmed, unless the end of the dash slithered off so far you had to retune the

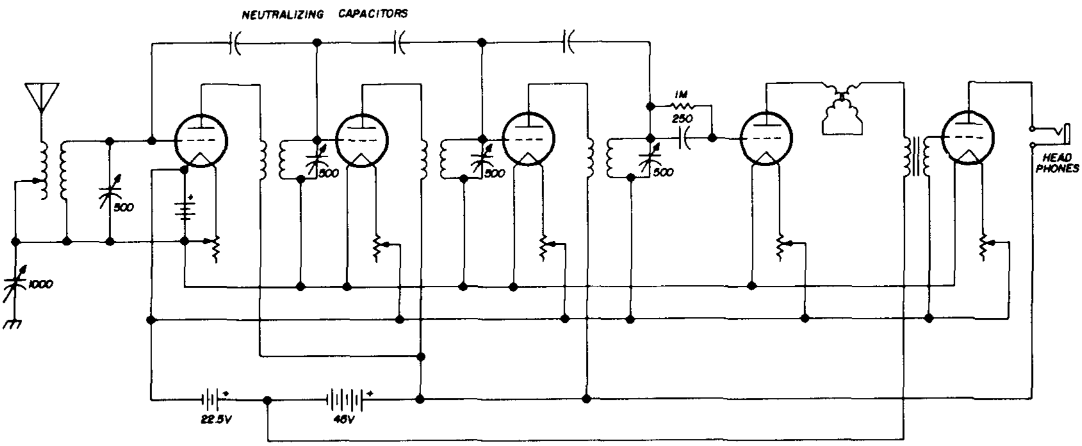


fig. 3. The Neutrodyne receiver, using 3 tuned rf stages. It was a bear to tune, but really brought in the DX. Note the neutralizing scheme — capacitor values were determined by cut and try.

RCA transmitter "appropriated" from a tugboat somewhere in NY harbor. This rig used four UV-202s and four Kenotron rectifiers. For "radiophone" you modulated two of the 202s paralleled in an oscillator, with the other pair paralleled as modulators. Each tube was rated at 5 watts. In the "telegraph" mode, all four 202s were paralleled for a full 20 watts out! But I never could work anybody with that old thing.

Under the bench was a collection of "slop jars," which bubbled and boiled so furiously when I pressed the key (despite the oil on the troubled waters) that I had long before given up trying to rectify the 110-volt ac line. A raw ac note was acceptable in those days, anyway. Plenty of rich guys used 852s (75 whole watts!) fired with straight ac, so why shouldn't I use ac?

"high" power and DX

As time went on I coaxed more and more out of the old 210 'til I had her receiver. Though one time when I was playing with an old WE 216A I did put a neat little hole in its corrugated plate.

And I got that voltage-fed Hertz a little higher up by using a bow and arrow to shoot a thread over a high branch of an old locust tree. With the thread I pulled up a string, followed by a rope, followed by the antenna itself. That helped.

By 1929 I had actually worked a VK. They had changed from OZ (for Oceania, Australia) to VK along with our switch to W from NU (for North America, U. S.). And, by the way, that Aussie was using an old 171A in his transmitter! In 1929, too, we had "international" ham bands. Prior to that you'd often find the foreigners in separate bands of their own.

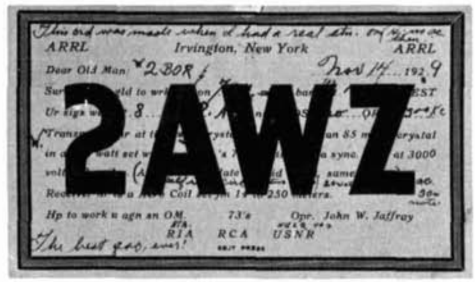
welcome to the shack

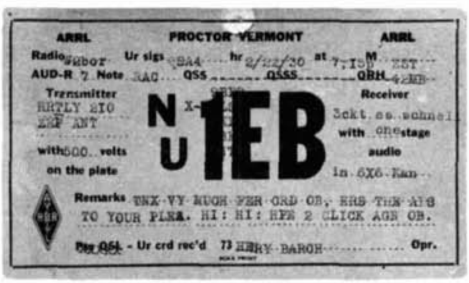
In front of me are some beaten-up old photos of the shack, taken at various times during the Twenties. Over there is a helix, an 8-inch-diameter coil of flat nickel-plated ribbon with one edge buried in a wood base. It came out of that old RCA tugboat transmitter. Yonder is the familiar old upright telephone mike. The plug-in coils of the receiver stand out clearly. Down at the end of the bench is an old long-wave receiver, an IP-501.

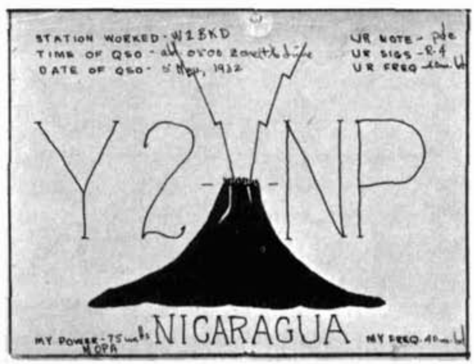
(Jaffray), NC3AY, 10016, U1QA, and many others.

now, a parting word

Because I still grow nostaligic at the smell of shellac and soldering flux, most







QSL cards typical of the early radio years.

Hanging on the wall amidst the ancient OSLs is a picture of Graham MacNamee, idol of announcer-worshippers, and certainly a far cry from today's "DJs." Back of the 3-circuit regen with the plug-in coils is arrayed a host of 45-volt B batteries and a 6-volt battery, along with the familiar old 4½-volt C battery.

and, of course, QSL cards

QSL bureaus were unheard of. Everything was "direct." A lot of OSLs were homebrew like the rigs themselves, especially during the Depression. But we relished 'em. Today the choice ones hang in my shack, yellowed with age, but protected by those fancy new cellophane holders.

You can see W1ZZAU (portables got calls like that!), old CM1ML, 2AWZ

of my gear today is still homebrew. But I'll admit it's mighty hard to equal the performance of today's ready-made equipment. Guess the best we can do is compromise by building a little and buying a little.

Still, it's nice to dream, isn't it – of UV-202s; WD11s, the beautiful music of an icw signal; KDKA; that first contact; that first overseas DX; I could go on for hours.

Those were the days, my friend.

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ham radio

television interference: an effective remedy

TVI can exist even with today's modern ham gear — here's one solution to the problem

I. Queen, W2OUX, 228 East 91 Street, Brooklyn, New York 11212

I've been an active ham for 36 years. During this time I've built many low-power rigs. I guess I enjoy working *on* a transmitter as much as working *with* it. I like all bands, so I'm partial to a long-wire antenna. Recently I began using an indoor wire. This antenna provides excellent DX reports, but it doesn't discriminate against TVI.

A few months ago I retired from home-brew rigs and purchased a Swan 350C, a transceiver with many good features and a lot of power for the money. I soon discovered that when operating on 20 meters, my favorite band, the Swan caused interference with my wife's TV programs, particularly on channel 2. (She watches a portable in the next room, about 12 feet from the rig and antenna.) On the other hand, 15 meters was perfectly clean on all low TV channels, but TVI showed up to a lesser degree on channel 9 and higher.

After discussing the problem with fellow amateurs, I realized that something had to give, and it turned out to be me. I would have to sacrifice some power. Fortunately this was not difficult to accomplish, and the difference in signal reports was insignificant.

the cure

It's quite possible that the modifications I made will apply to equipment other than Swan. Here's what I did, in the order of effectiveness, to cure the TVI problem:

1. Input to the driver stage, a 6GK6, was reduced, which decreased harmonic output.

2. Input to the final, which uses a pair of 6LQ6/6JE6 tubes, was reduced from 360 to 200 watts.*

3. Capacitors (1 kV disc type, 0.001

*This is a decrease of about 2.5 dB, which is barely perceptible under *ideal* conditions. It's unlikely that the receiving station could tell the difference between 360 and 200 watts under actual band conditions. *editor.*

μF) were placed across filament, high-voltage, medium voltage, and bias terminals — right at the Jones plug. (These are leads between the transceiver and power supply.) Also I shortened the unshielded cable between the rig and power supply, which reduced radiation from the cable.

other changes

The Swan has three supplies: 850, 275, and 215 volts. This last voltage is obtained through a dropping resistor. The Swan schematic shows that the 850 volts is the sum of two supplies in series: 275 and 575 volts. I separated these supplies and used them independently. The 575 volts was applied to the final plates (instead of 850 volts); then I added a 150-volt zener, fed from the 215-volt supply (**fig. 1**). The 150-volt supply is now used for the final and driver screens, The "new" and "old" voltages are listed in **table 1**.

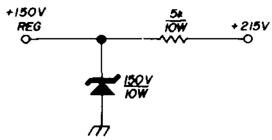

fig. 1. Zener diode added to the Swan 215-volt supply for final and driver screens to reduce input power for TVI reduction.

commercial data

Lest these changes seem drastic, I'll reference an article appearing in *Sylvania News.*[1] This article discusses several tubes, including the 6JE6. The following optimum values are suggested for the 6JE6:

plate voltage	500
screen voltage	125
bias voltage	-85
plate current	222 mA

These values are recommended in the Sylvania article for class-C cw operation. For class AB1, the same maximum plate and screen voltages are recommended, plus

idle plate current	40 mA
bias voltage	-44 Vdc

Note that these are still slightly below those for the "new" values given in **table 1.**

table 1. Voltages for the Swan 350C before and after the TVI modifications.

	driver		final	
	plate	screen	plate	screen
new	270	150	525	150
old	270	270	850	210

results

When the changes described above were incorporated, TVI was greatly reduced. I can now monitor a portable TV receiver with its single collapsible rod antenna about two feet from my indoor transmitting antenna. On channel 2, barely visible lines appear; but previously the picture was completely wiped out! With the TV set in the next room, no lines are visible at all. It's almost impossible to tell when I'm on the air. The loss in transmitter power is less than 2:1, so the sacrifice is small.

further power reduction

If you wish to reduce transmitter power still further, disconnect the input capacitor to the filter in the 275-volt supply. The voltage will be decreased to about 200 volts. Input to the driver will be much lower, reducing harmonic output still further; and the dc input to the final will be about 125 watts. The lower voltage will also be applied to the tubes in the receiver section; however, I didn't notice much loss in sensitivity. If you have a really severe TVI problem, this certainly should do the trick.

reference

1. W. D. Murphy, "Horizontal Deflection Tubes as Power Amplifiers," *Sylvania News,* Vol. 31, No. 4, Winter, 1964. Sylvania Electronic Components, Waltham, Massachusetts 02154 ($1.00 per bound volume).

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charge flow in semiconductors

This will help you understand the principles of transistor theory

Clifford J. Klinert, WB6BIH, 520 Division St., National City, California 92050

Electron flow in vacuum tubes is not hard to understand, but many hams find it difficult to shift from tube to transistor theory. Indeed, a physicist could spend most of his life studying transistor theory, only to find that the more he knows the more there is to learn. Fortunately, it's possible to simplify transistor theory so that almost all of the happenings in the transistor can be explained in simple terms.

This article is written for the ham who wishes to understand the basic interactions that take place in the six-thousand-plus different types of transistors on the market today.

Whether a material is a conductor or a dielectric depends on the quantity of electrons that are rigidly bound within the material's atomic structure. If the material has an excess of loosely held electrons, the electrons can be easily disturbed by an external influence such as an electrical force. The material is then said to be a conductor of electricity. If, on the other hand, the material has few loosely held (free) electrons, the material has a high resistivity. The electrons are not free to distribute themselves readily, and the material is called a dielectric or insulator.

Transistors are made from crystalline substances called semiconductors. The atomic structure of these substances places them about midway in the resistivity scale between conductors and dielectrics. Modern transistor theory is based on how these crystal substances behave when their atomic binding forces are disturbed in a controlled manner, as by adding impurities. This is the basis of the discussion to follow.

atomic structure

According to the Danish physicist, Neils Bohr, the atom has a positively charged nucleus surrounded by orbiting electrons. Each orbit has a distinct number of electrons, and each electron has a distinct energy level. The electrons in the outermost orbit have the highest energy level (highest momentum). They are also farthest from the binding force of the atom's nucleus, hence they can more easily break free from the parent atom.

The crystal substances used in today's transistors and diodes are germanium and silicon. The outer orbits of these materials have four electrons. The balance between nucleus and electrons prevents the material, in its natural and undisturbed state, from acquiring any more electrons. Thus in an ideal crystal, where the electrons are bound firmly within the structure, no conduction occurs. The material is, theoretically, a perfect dielectric. A two-dimensional representation of the structure is shown in **fig. 1.** Here, each atom shares its four electrons with its neighbors.

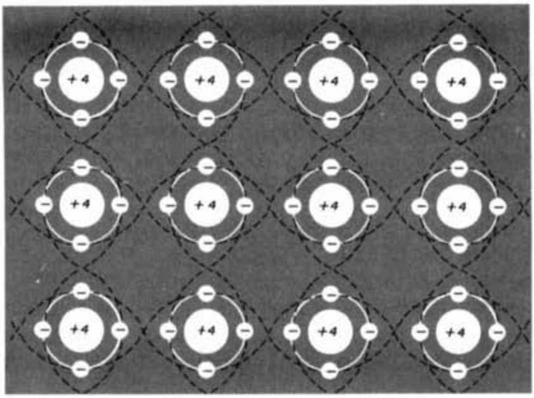


fig. 1. Atoms bound together by sharing electrons in a pure silicon or germanium crystal.

Free-moving electrons are necessary for conduction in any substance. If the electrons are held tightly in the structure, as in **fig. 1,** no conduction occurs. However, if enough energy is available, an electron can be freed from the bond.

Heat is one form of energy that can free electrons. At room temperature, there is enough energy to free some electrons and provide conduction. The more heat put into the crystal, the more free electrons, and the higher the conduction.

holes

Every discussion on transistor principles mentions holes and hole conduction. This is perhaps one of the most difficult concepts to grasp. Whether you're talking about transistors or doughnuts (they're both made of matter), a hole is a very real thing and can't be ignored. I'll try to explain why.

A crystal of pure germanium or silicon is a dielectric. No conduction occurs unless an electron breaks free from the bond existing between neighboring atoms. If energy is applied, however, an electron is free to move through the structure. Conduction is then said to exist.

Electrons possess a negative charge; hence they are called negative-charge carriers. When an electron is freed from its bond, a hole is said to exist. What is a hole? It's either something or nothing, depending on your viewpoint. In electron physics it's a very real something.

When an electron is knocked out of its orderly path in a substance, the space it formerly occupied *must* be accounted for. The space vacated by an electron is called a positive-charge carrier. It can be shown mathematically that this carrier

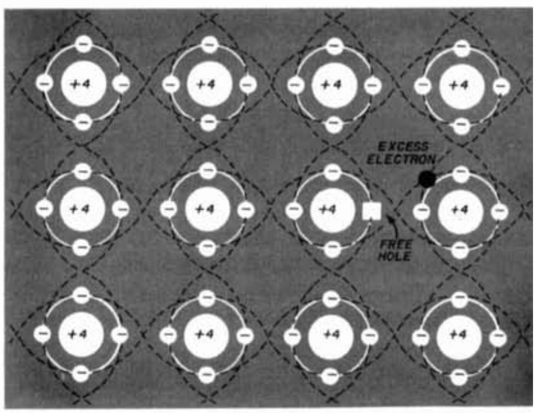


fig. 2. Free hole and free electron created by thermal energy breaking the bonds.

moves from place-to-place within the substance. Holes can carry a charge, because they cause the structure to become positive *without* the electron. The idea of holes and electrons is shown in **fig. 2.** It's important to understand that the hole *must* exist, because making a hole in nothing would be meaningless. It may be difficult to visualize something that is really nothing, but the hole does *do* something.

The electron, unlike the hole, can exist by itself and doesn't have to hop from one atom to another. It can move more independently through the crystal, and it happens that the electron moves about twice as fast as the hole.

Fig. 3 demonstrates the idea of conduction. We use a piece of silicon with a battery connected across it. The battery is simply a pump that pumps electrons from its positive end out its negative end. Half as many holes flow in the opposite direction. The holes are pumped out of the positive side of the battery and into the negative side. Whenever a bond in the atom is broken to create an electron, a hole is formed, so an equal number of holes and electrons exists. However, since the electrons move twice as fast as the holes, there will be *twice* as much

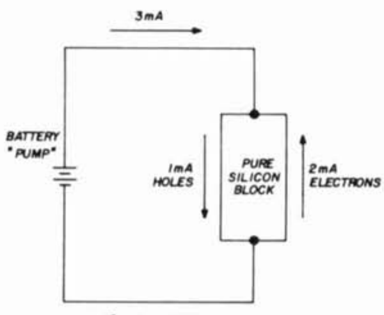


fig. 3. Charge flow. Current is the sum of the holes and electrons and is from positive to negative.

electron current as hole current. If we assume a two-milliampere electron flow, then there will be a one-milliampere hole flow in the opposite direction.

Which way does the current flow? This is an ambiguous question, because current actually flows in *both* directions. If only the word *current* is used, it usually means a charge going from positive to negative in the circuit. In most textbooks (and in this article), current always means the *total* charge flow in the positive-to-negative direction. If we have two milliamperes of electron charge flowing from negative to positive, and one milliampere of hole charge flowing from positive to negative, *three* milliamperes of current will flow from positive to negative.

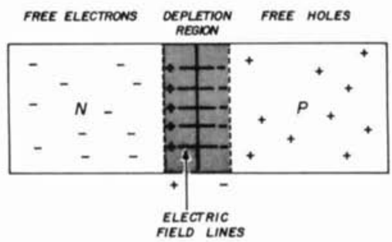


fig. 4. Depletion region in p-n junction.

doping

As stated earlier, the semiconductor material is not a very good conductor, because not many charge carriers are freed from the bond between atoms. However, it's possible to create charge carriers in larger numbers by a process called *doping.*

Suppose we add some atoms with either three or five electrons in their outer orbits to the pure germanium or silicon. Several elements possess this structure. Arsenic and indium are the most popular materials for doping. The foreign atoms in these materials will mix into the crystal and form bonds with its pure semiconductor material. However, if only three electrons exist in the outer orbit of a doping atom, a hole will exist in the structure. Just the opposite happens with five electrons instead of four. In this case there's an extra electron. This is how *free-charge carriers* are created.

If we dope a piece of silicon with atoms that have only three electrons in their outer orbit, the majority of the charge carriers will be *positive holes.* This is called P-type semiconductor material. If the doping atoms have five electrons in the outer orbit, then we have electrons as the majority-charge carriers. This is called N-type material.

the p-n junction

Suppose a block of N material is attached to one of P material. The electrons are still free, bouncing around with thermal energy in the N-type material, and the holes bounce around in the P-type material. The charge is still balanced, and the holes and electrons move randomly. Suddenly an electron strays across the P-N junction. It is instantly captured by a hole and held tightly in the bond. An electron has left the N side, so the charge balance is upset, and the N side is positive by one charge. For every charge carrier that wanders from one side to the other, a line of electric flux is formed. Charges continue to bounce across the junction, driven randomly by heat energy, building up an electric field at the junction. The positive polarity of the field is on the N side, and the negative polarity is on the P side. Soon the field builds up to a point where the charge of the field overcomes the thermal energy. Since there is a large negative charge on the P side, electrons are repelled from crossing the depletion region to the P side. **Fig. 4** shows this situation. The charged area is called the depletion region, because all electrons and holes have combined. All the moving charges have depleted and are in equilibrium. After studying **fig. 4,** this section should be reviewed, because this is an important concept.

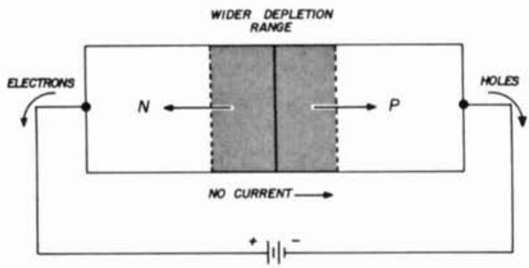


fig. 5. Reverse bias. The depletion region is widened so that no current flows.

the diode

Now suppose we attach a battery across the P-N junction. The positive side of the battery is connected to the N-type material; the negative side to the P-type material. The battery pumps holes into the negative side and pumps electrons into the positive side. At each end of the semiconductor material, charge carriers of one kind are pumped out and replaced by those of the opposite kind, which recombine and become an inert part of the structure. This is illustrated in **fig. 5.** As a result, more charge carriers are depleted, and the depletion region becomes wider. This makes the barrier higher, which prevents carriers from crossing by heat energy. Since no charge carriers can cross, no current flows.

Now suppose the battery polarity is reversed, as in **fig. 6.** The battery pumps electrons into the N material and pumps holes into the P material. This increases the charge carrier concentration. More

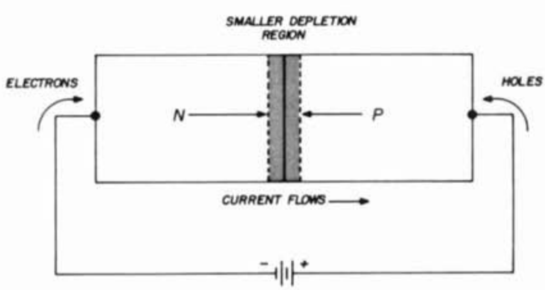


fig. 6. Forward bias. The depletion region is reduced, allowing current to flow.

holes are on the P side, and more electrons are on the N side. Thus the depletion region is smaller. When the barrier is small enough, the charge carriers will cross. Carefully note that conduction *is not* a result of carriers being attracted by the battery. Conduction results from the random movement of carriers that have increased in quantity. Conduction also results because of the lowered barrier.

So now we have a diode. But the real magic is yet to come.

the transistor

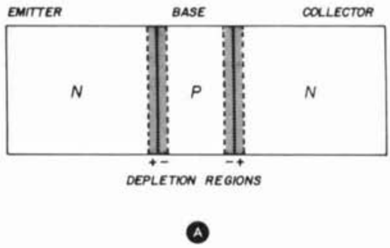
Suppose we add another N-type material to the P side of the P-N junction. This is then an NPN arrangement, as shown in **fig. 7.** The P part is usually made very thin; 0.001 inch or less. Since this is a transistor, the N-type material is called the emitter, the P-type material is the base, and the N-type material is the collector.

Batteries and ammeters have been connected to the transistor **(fig. 8).** The batteries act in the same way as in the diode discussion, i. e., pumping holes out of the positive side and pumping electrons out of the negative terminal. The batteries can also be thought of as pumping electrons into the positive side and pumping holes into the negative side. It will be necessary now to call upon some circuit theory to explain the current flow in **fig. 8.**

Kirchoff's law states that the sum of the currents in a closed loop must be equal to zero. This means that the sum of the currents coming out of a branch must equal the sum of the currents going in.

Consider the base-emitter junction. Note that this junction is forward biased, and the depletion region is lowered. The electrons in the emitter can now cross the low depletion region as can the holes in the base. The electrons move about *twice* as fast as the holes. With this thought in mind, suppose that two milliamperes of electron current flow from emitter to base, and one milliampere of hole charge flows from base to emitter. Since electrons and holes move in opposite directions, they will *add* in the emitter circuit, so that three milliamperes will flow in the emitter circuit. The I_E meter will read 3 Ma. The electrons flowing from emitter to base have tremendous velocity, and most cross the base into the collector. About one percent fall into holes in the base; but for practical purposes, we'll assume they all enter the collector.

The battery is connected so that the



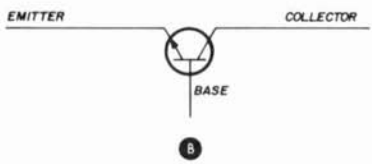


fig. 7. The npn transistor. (A) shows the junction of two materials having an excess of free electrons (n type) and an excess of positive charge carriers, or holes (p type). The schematic symbol is shown in (B).

collector-base junction is reverse biased. Therefore, electrons are pumped *out* of the collector. Before the emitter current becomes effective, no current can flow because of the reverse bias. But the two milliampers flowing into the collector are an *excess.* These electrons are pumped out of the collector, causing two milliamperes of current to flow. The meter, I_C, will read 2 Ma.

To find the base current, I_B, we must consider the connection between the batteries. Three milliamperes are pumped out of the emitter by the emitter battery, B_E. Since two milliamperes are pumped out of the collector battery, B_C, two of the three milliamperes from B_E *must* flow through B_C. One milliampere has to go somewhere, so it must go into the base. Recalling that one milliampere of hole charge flows from base to emitter, the circuit checks out.

amplification

If the emitter-base voltage of **fig. 8** is varied, thus varying base current, then the current from the emitter varies. This varies the collector current. A small change in base current causes a much

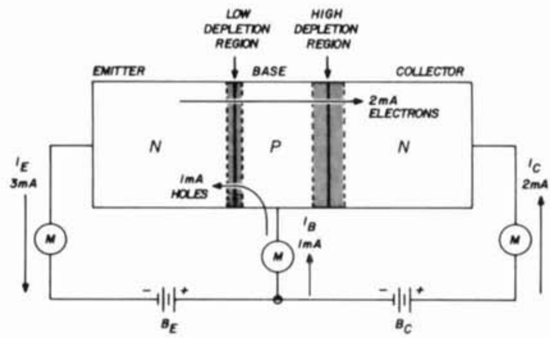


fig. 8. Npn transistor with batteries showing current flow. The collector current is larger than the base current, causing amplification.

larger change in collector current. Thus we have gain, or amplification. The dc current gain of a transistor, called beta (β), is the ratio of collector-to-base current:

$$\beta = \frac{I_C}{I_B} = \frac{2}{1} = 2$$

If one milliampere flows into the base, two milliamperes will flow from the collector.

doping levels

A gain of two is pretty poor by today's standards. The problem is due to the large base current. If the base current could be reduced, while retaining the same collector current, the gain could be increased.

One way to reduce base current is to reduce the flow of hole charges from base to emitter, because this is the only significant charge flow from the base. The hole charge flow can be reduced by reducing the amount of base doping, which impedes the number of holes in the base. If base doping is reduced by one hundred times, the hole current from the base will be reduced to 0.01 milliampere. If we make this modification to **fig. 8,** the base current will be 0.01 Ma. Since two milliamperes flow from the emitter, two milliamperes will flow into the collector. The dc current gain is then

$$\frac{I_C}{I_B} = \frac{2}{0.01} = 200 \text{ mA}$$

In modern transistors, the emitter is doped from 500 to 1000 times more heavily than the base. Several factors limit the amount of doping. If the base is doped too lightly, the device becomes an insulator, and no current flows. It's desirable to dope the collector as heavily as possible to reduce its series resistance. However, this reduces the breakdown voltage. If the base is made thinner, gain is increased, because there is less chance for an electron to cross the base and be caught by a hole. If the base is *too* thin, the two depletion regions on either side will join when high voltage is applied. Then the transistor will short circuit, causing destructive current flow.

conclusion

I have made omissions and approximations to keep the discussion simple. Many more facts about semiconductors are available in hundreds of textbooks. The main purpose of this article is to present the basic concepts of these marvelous devices in an easy-to-understand manner. I hope I've succeded.

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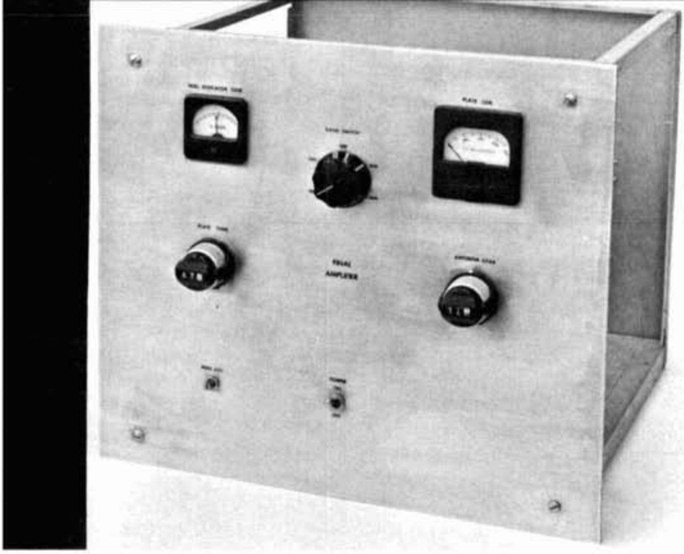

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The Eimac 4CX1500B

in a circuit

with novel tuning

and bias-control features

Irwin R. Wolfe, W6HHN, 3467 Rambow Drive, Palo Alto, California 94306

The 4CX1500B ceramic tetrode is used in many commercial high-frequency transmitters, but this tube seems to have been overlooked by amateurs. It has some features that should appeal to the "home-brew" ham, such as:

1. Lower grid-drive requirement than for 1-kW triodes.

2. No neutralization.

3. Low intermodulation distortion in linear-amplifier service.

4. High plate dissipation, which means longer tube life and less chance of tube destruction when operated in an off-resonant condition.

As with other tetrodes in this class, certain design criteria and precautions must be observed with the 4CX1500B to obtain satisfactory operation within published ratings. Some of this tube data is presented at the end of the article. It is recommended that those wishing to build the amplifier described here become familiar with all the characteristics of the tube (reference 2).

amplifier circuit

Standard components are used throughout. Although vacuum variable capacitors are shown in the schematic (**fig. 1**), air-dielectric variables can be used, and a multi-turn dial won't be necessary (see photo).

The amplifier employs an untuned input circuit and a conventional pi-network output circuit. The rf drive signal is terminated in a 50-ohm noninductive resistor through which grid bias is supplied to the tube. To improve the input-impedance match at the three higher-frequency amateur bands, three untuned grid coils are used to approximately cancel the input capacitive reactance at the grid. Although the input circuit is untuned, only 40 watts peak power is required to drive the amplifier in the frequency range 3.5-29.6 MHz. (The grid coils and switch aren't shown in the photo of the input compartment, since they were installed after the photo was taken.)

A Barker-Williamson coil assembly is used in the output circuit, with the 10-meter coil rearranged to shorten leads to the tube plate.

metering

Only two meters are used: a zero-center tuning meter and a plate milliammeter. Screen current is negative and does not require monitoring.

The zero-center meter permits quick adjustment for optimum drive and loading over any part of the band. It operates in the following manner:

The rf input and output circuits are sampled by capacitive dividers, then rectified and filtered. The dc outputs are connected to each side of a potentiometer, while the arm connects to ground through the zero-center meter. The diodes in this circuit are connected to provide a negative voltage from the input and a positive voltage from the output. The rf drive voltage then causes the meter to read to the left of zero, while the voltage from the output circuit opposes this action.

The 5-pF capacitor in the output sampling circuit is an adjustable wire probe coupled to the tank coil. The dc voltage at the 10-k zero-adjust pot can be adjusted by varying the position of this probe.

The voltage at the midpoint of the capacitive divider on the input circuit is about 3 volts peak (20:1 divider and -60V bias). The voltage at the midpoint of the output capacitive divider should be about the same.

In preliminary tuning, the usual procedure is followed using a two-tone signal and oscilloscope. Adjustments are made on drive and loading until the scope indicates minimum waveform distortion at the 2-kW PEP level. At this point the potentiometer is adjusted for a zero reading. Thereafter, when changing frequency, it's only necessary to resonate the plate circuit and adjust the drive and loading capacitor for a zero meter reading again.

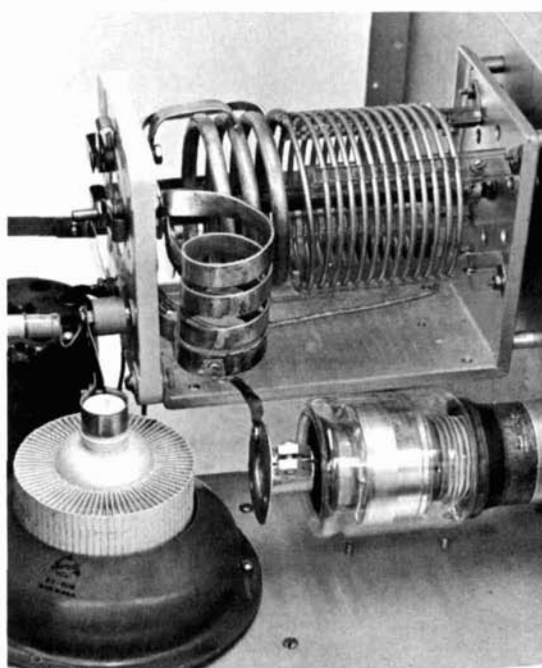
power supply

The power supply is conventional and uses silicon diodes in series in each leg of a bridge rectifier to deliver 2900-3200 Vdc, depending on line voltage. One-half of the secondary voltage at the transformer center tap is dropped by a resistor and connects to two series VR125 tubes, then to ground. This supply provides regulated 250 volts dc for the screen.

A single-section LC filter is used in the plate supply, and an electrolytic capacitor provides additional screen-voltage filtering.

A bias supply, using a small 115-volt

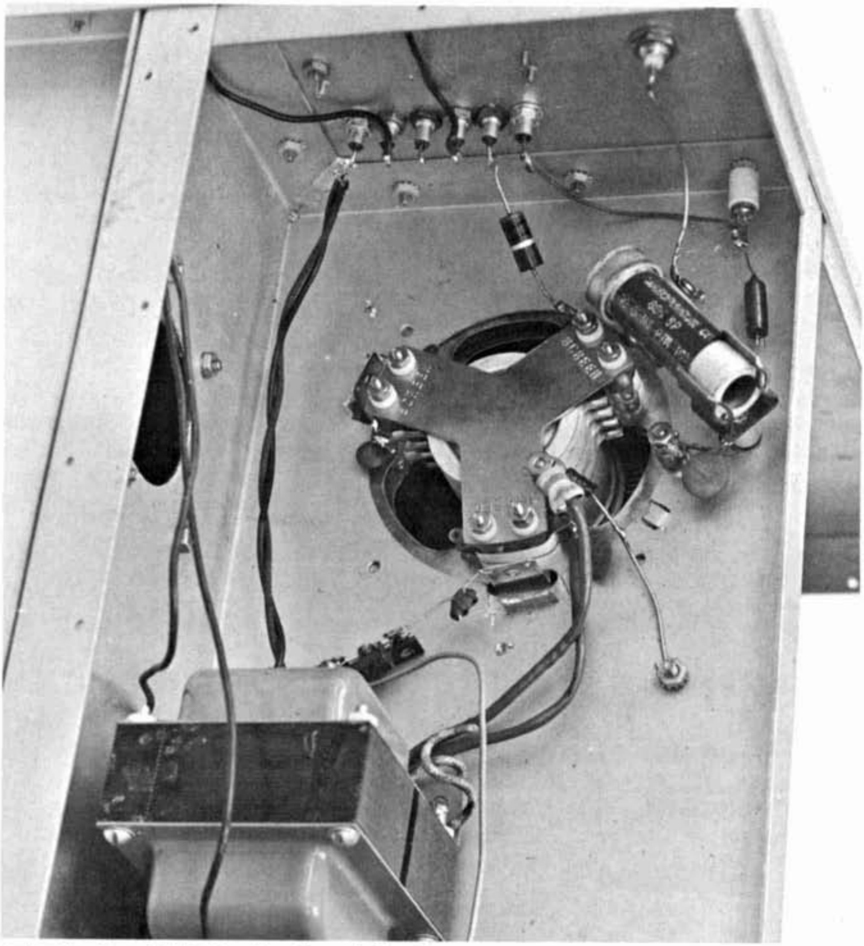
Tank circuit of the amplifier. The B&W 10-meter coil has been rearranged to provide short rf leads to the tube plate.



isolation transformer with a silicon bridge rectifier and RC filter, uses two parallel-connected potentiometers as voltage dividers. These pots supply bias voltages for "standby" and "operate" modes.

The auxiliary relay changes bias during standby periods to provide near cutoff plate current (50 mA).

With such light loading of the plate supply during standby, the plate voltage



Underchassis view. Grid circuit coils and line fuse were added after the photo was taken. Note arrangement of filament transformer leads and feedthrough capacitors for input voltages.

bias control

For good linearity, a plate resting current of 250 mA is required. During standby and talk periods this amounts to 800 watts plate dissipation, which runs up the power bill as well as the temperature of the shack. To remedy this situation, an auxiliary relay is connected to operate with the antenna transfer relay.

can soar to about 4000 volts, which imposes a strain on the filter capacitors. This problem was resolved by tuning the filter choke with a capacitor to approximately the supply ripple frequency of 120 Hz. With this circuit, a variation of only 200 volts exists between 50 mA and 250 mA loading. During "operate" mode, plate current varies between 250 and 350 mA. Overcurrent protection is provided by a relay in the negative side of the plate supply. A rheostat across the relay coil is used to adjust trip current. Circuit breakers are provided for the bias supply, ½-inch angles that form the box enclosure. The top cover of the amplifier is perforated aluminum to permit venting of blower air. The rear panel contains the 6-terminal board, coax connectors, and a

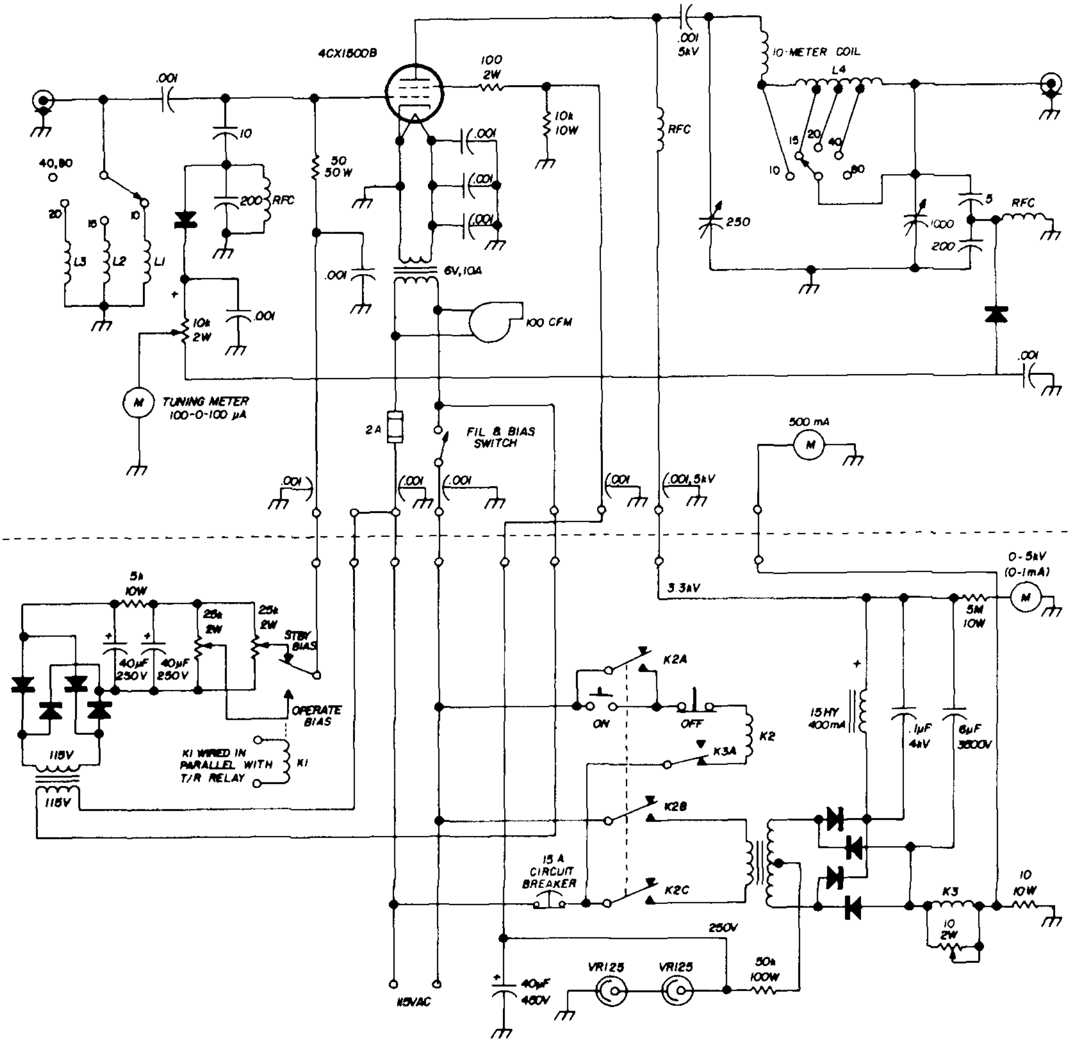


fig. 1. Schematic of the high-power 5-band amplifier. Grid coils are self-supporting, ½-inch dia., wound with no. 16 tinned copper wire. Ten meters, 5 turns 1¼-in. long; 15 meters, 7 turns 7/8-in. long; 20 meters, 13 turns 1-in. long.

filament transformer, and blower.

construction

Amplifier layout is designed for short rf leads. No neutralization or parasitic suppression is required. Aluminum plates are used, which are screw-fastened to panel fuse for the filament transformer. To minimize TVI, all electrical connections to the cabinet are made through feedthrough capacitors.

A tube chimney is used with the 4CX1500B socket to confine and direct blower air through the plate cooling fins.

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tube characteristics

The maximum temperature rating for the 4CX1500B anode is 250° C. As an added precaution, it might be worthwhile to consider some sort of monitoring device for the tube. An article describing temperature sensors for high-power amplifiers, using scrs and thermistors, appears in an earlier issue of *ham radio.*[1] These circuits are extremely simple to build and are a good investment for the amateur interested in protecting his vacuum tubes.

heater voltage

Published ratings for the 4CX1500B heater is 6.0 volts. This means that heater voltage must be maintained within ±5 per cent as measured at the *tube socket terminals.* The heater voltage must be applied for at least 3 minutes before other operating voltages are applied.

screen grid

It is not uncommon for tetrodes to exhibit negative screen current. This is a prominent characteristic of the 4CX1500B and is normal for the circuit described here. However, the maximum rated power dissipation for the 4CX1500B screen is 12 watts, which should not be exceeded. Peak screen voltage times indicated dc screen current equals the approximate screen input power, except when screen current is near zero or negative.[2]

control grid

The control-grid dissipation rating of the 4CX1500B is 1 watt. Design features of this tube provide low intermodulation distortion, even when the grid is driven into the positive region. The tube can therefore be operated in Class AB_2, which is recommended in the manufacturer's literature.[2]

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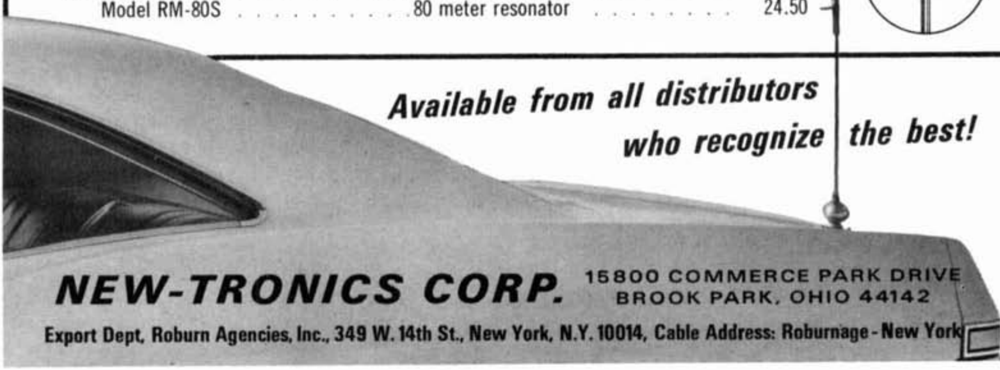


some observations regarding transmitter power levels

The difference between 100 watts and 1000 is not as great as you might think — on-the-air communications suffer little from lower power levels

Courtney Hall, WA5SNZ, 7716 LaVerdura Drive, Dallas, Texas 75240

The purpose of this article is to explain the ability of a 10-watt transmitter to span a continent with almost the same ease as a 100-watt rig. Experience has shown this to be true, and investigations have indicated that such phenomena should not be regarded as unusual.

In all of this discussion it is assumed that when transmitter power is changed, all else remains the same (frequency, antenna, vswr, receiver sensitivity, etc.). Also, power levels referred to can be input power or radiated power so long as it is the same in all cases; relative change and its observed effect are the main considerations. Transmitter efficiency and antenna gain and efficiency are assumed fixed.

on-the-air observations

Two years of operating experience with 50-watts cw seemed to indicate that I got out about as well as the fellows using 75- or 100-watt rigs. Although there was 50 watts difference between my rig and the 100 watters, this only amounted to 3 dB which seemed small in relation to a typical 140-dB path loss. The personal opinion grew that atmospheric conditions had a lot more to do with "getting out" than a few dB of transmitter power.

To gain more insight, I designed and built a small 12-watt, 40-meter cw transmitter which would deliver 8 watts output into a 50-ohm resistive load. I have used it for about six months on the air with the same antenna as was used for the 50-watt rig. This antenna is nothing special; just a 40-meter dipole about 15 feet above the ground, fed with RG-58/U. No balun is used.

It is difficult, if not impossible, to tell from the calls, QTHs, and signal reports in my log when I changed from 50 to 12 watts. I seem to get out nearly as well with only 12 watts. Since 12 watts is about 6.2 dB below 50 watts, I should average one S-unit lower in signal strength reports, but even this is not evident. I have received 559 to 599 reports from coast-to-coast, from Canada to Mexico City on 40-meters cw with both rigs. Furthermore, I have not noticed any greater difficulty in making contacts with the 12-watt rig.

laboratory observations

Still, I had no feeling for how a signal change of 3 dB, 10 dB or 20 dB sounded. To find out, I assembled the equipment shown in **fig. 1**.

The 1-kHz audio oscillator had a sine wave output, and its level control allowed the output to be adjusted from zero to approximately 10 volts rms. A key was used to simulate actual code reception, rather than a steady tone. The step attenuator was a commercial type which could be adjusted from 0 to 120 dB in one-dB steps. To achieve a close match for the output impedance of the attenuator, an 820-ohm resistor was connected in parallel with the 2000-ohm phones.

To begin the experiment, the attenuator was set for zero-dB attenuation and the oscillator level control was adjusted for a comfortable volume level in the phones, such as would be used for code practice. Then, 3-dB attenuation (half power) was switched in on the attenuator; this caused a slight decrease in volume, but it would be extremely difficult to distinguish between the two levels without being able to switch between the two. In other words, if you listened to one level on one pair of phones, then took those phones off and put on another pair of phones to listen to the other level, they would sound almost the same.

Next, the change in volume corresponding to 10-dB attenuation (one tenth power) was observed. The signal was noticeably weaker, *but not so weak that you would take the trouble to increase gain if you were practicing code.* It was still a good signal, just a little below optimum. This observation explains, to me at least, why a 10-watt transmitter will sound fairly good to a receiving station if a 100-watt transmitter sounded very good, all else being equal.

Attenuation of 20 dB (reduction of power by a factor of 100) made the signal pretty weak, but it was still easily readable; 30-dB reduction was extremely weak and difficult to read, and 40 dB was barely perceptable. When the signal was increased to 10 dB above the original zero dB, or comfortable level, the volume was uncomfortably loud and almost painful.

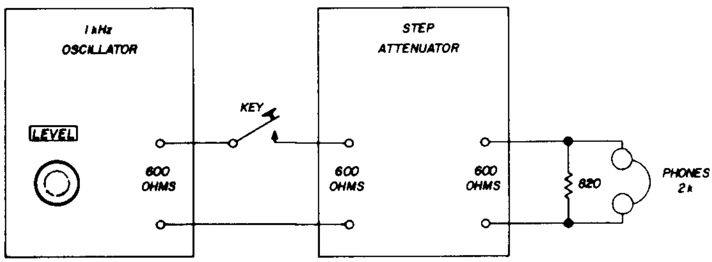


fig. 1. Bench test circuit for determining the effect of different power levels.

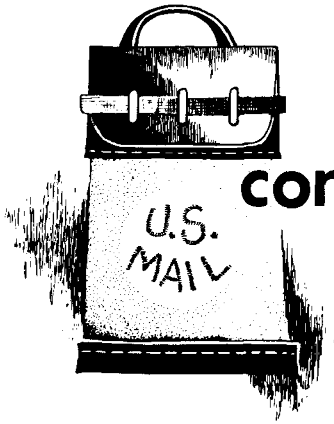
I believe the above observations show that the novice limit of 75 watts is far in excess of the number of watts required for casual cw work, and that there is no need to feel ashamed of your 100-watt rig if a 10 watter gets as good a report as you do; 10-dB difference in power may represent a lot of watts and dollars, but it doesn't impress the ear that much.

To put all of the above in its proper perspective, the following should be mentioned. It's not the easiest thing in the world to describe in words how loud a sound is; I have tried to describe the laboratory observations as I heard them, but the dynamic range of my ears may be average, above average or below average. Much depends on the "comfortable" level you start with at zero dB. The laboratory observations simulated ideal conditions; there was no receiver noise, no interference and no fading.

I have no argument with the man who says the more power you have, the better chance you have to get through. He is absolutely right. My point is that you can do more with just a few watts than perhaps many hams realize.

It is interesting to express the ratio of Novice power limit to General power limit in dB: 11.25 dB. Another point to remember is that receivers with cw agc tend to make the 10- and 100-watt rigs sound the same, the difference appearing on the S-meter. Finally, the laboratory observations should give an indication of what to expect from filters; at least 30 dB of attenuation should be provided for unwanted frequencies which have a signal strength equal to the desired signal.

ham radio



comments

motorola fets

Dear HR:

I enjoyed reading the September issue of HR – especially the piece on the fm receiver. Great!

I noticed that the authors referred to an MPF105 and MPF107 as being better than an MPF102 in the front end of the unit. Tain't so! The MPF105 is rated to a much lower frequency than 2 meters. The MPF107, however, is good to 3/4 meters. Perhaps he meant to say MPF106 and MPF107 there. At any rate, the MPF designation has been obsolete on all but the MPF102 series for almost a year now. This could give your readers a bit of a problem. Here are the new Motorola numbers for the devices:

MPF102 . . . no change
MPF103 . . . 2N5457
MPF104 . . . 2N5458
MPF105 . . . 2N5459
MPF106 and 7 now split into three types: 2N5484 through 2N5486

Also, there is a new series of MPF102 devices – 2N5668, 69, and 70. These are simply more tightly controlled MPF102s.

Doug DeMaw, W1CER
ARRL Technical Editor

injection lasers

Dear HR:

The excellent article on injection laser experiments by Ralph W. Campbell (November, page 28) was of particular interest to me. I am convinced that lasers have a definite role in amateur communications, and it is encouraging to see experimenters such as Mr. Campbell pioneering the way.

Regarding communications with modulated light emitting diodes, I would like to point out that Henry E. Roberts and I have covered the subject in some detail in a pair of articles in the November issue of *Popular Electronics.* One article is a tutorial, and the other is a construction project for a 1,000-foot range LED voice communicator, The latter is being marketed in kit form by MITS, Inc. Price of transmitter and receiver, both of which are quite compact and battery powered, is $32.00 postpaid. For more information, write the company at 4809 Palo Duro, NE, Albuquerque, New Mexico 87110.

While the light emitting diode is actually superior for many voice communications experiments at the present time, the laser does have some special benefits, particularly peak power. For those experimenters desiring to work with semiconductor lasers, I would discourage the purchase of the RCA TA-2628. The TA-7606 uses a new technology and is far superior. For example, the latter laser has *a threshold for lasing of about 4* amps – considerably less than the

TA-2628. Also, lifetime will be longer with the newer laser. There are numerous other considerations and the experimenter will be wise to consult some of RCA's excellent data pamphlets, such as "GaAs Lasers and Emitters" OPT-100, before actually selecting a laser. As these devices can be "zapped" quite easily, particular care to circuitry requirements should always be observed.

Forrest M. Mims
Albuquerque, New Mexico

fm receiver frequency control

Dear HR:

Several weeks ago I acquired a surplus Motorola base station. The receiver was easily aligned to 146.94 MHz, the national calling frequency. Sensitivity was better than 0.1 easy microvolt to crack the squelch, and 0.3 for 20-dB quieting. (The signal generater was an HP-608F.)

The set uses a 12.455-MHz second oscillator and a 455-kHz Permakay filter. This filter (TU-540S) is narrow – about 10 kHZ. Even after tuning the first oscillator for nominal input-frequency, more than half the signals, sufficient to open the squelch, are unintelligible, This is for three reasons: Low levels, as shown by monitoring an i-f grid-return; Signal deviation too wide for filter in use; And signal frequency off center of response. A considerable proportion of unintelligible receptions was due to the last, which is the subject of this note. The problem is well known on the 470-MHz commercial band, and is handled in part by afc to the first crystal oscillator. In the 160-MHz band the practice seems to depend on oven-mounted first-oscillator crystals, and frequent touchup of fleet frequencies by a service shop.

Compared to afc, receiver standby with "un-rubbered" quartz has some advantages. The center response can be precisely set with a counter, and tends to stay put. Application of afc to crystals is not so easy at 160 as at 470 MHz. In any case, it degrades stability.

Because of spectrum congestion, trends are to split channel allocations. In two-way fm, 60 to 30 to 15 kHz. In two-way aeronautical service, a-m, 100 to 50, and likely, 25 kHz. How to deal with narrow-band stability problems seems to be of both commercial and amateur interest.

Why not use the crystals for standby, and automatically transferring to afc when receiving a carrier sufficient to open the squelch? In fm receivers the necessary discriminator and amplified squelch already exist. For a-m receivers these elements have to be added. To be added in either case are switching circuitry controlled by carrier/noise-operated voltage, and a vco. To impose lesser demands on inherent vco stability, the second oscillator looks like the place to enter. As mentioned, this is at 12-MHz in a typical case. Transfer time-constants must meet various criteria, one being that reception must be continuous to keep the squelch open. Ideally, the vco would start, nobreak, from synchronism with the crystal, and proceed within a few multiseconds to discriminator zero.

Has this been done already? Where can I get details?

Paul D. Rockwell, W3AFM
Chevy Chase, Maryland 20015

digital counter

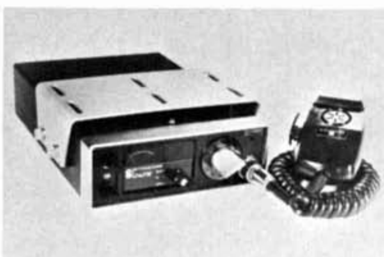
Dear HR:

I wish to thank you for a very fine magazine, in particular the articles by Bert Kelley, K4EEU. I built the digital frequency counter described in the December, 1968 issue, and used it in the September, 1969 and February, 1970 ARRL Frequency Measuring Tests. It enabled me to be among the top group who had accuracies better than 0.4 parts per million on both tests. In fact, my readings coincided exactly with the umpire on the February, 1970 run.

Joseph Czerniak, W8NWU
Muskegon, Michigan

new products

fm transceiver



Standard Communications Corporation, the largest manufacturer of vhf marine equipment in the world, has developed a professional quality vhf-fm transceiver specifically for amateur use. Standard has applied the latest solid-state technology to build a unit that is rugged and compact, and makes mobile installation practical in nearly any vehicle or aircraft. In addition, it's fully portable with the addition of a battery pack.

The Standard model SR-C826M features 12 crystal-controlled channel capability (4 channels factory installed), 10 watts rf output power, low power consumption, mosfet rf amplifiers and mixer, noise-operated squelch, high-low power switch, illuminated dial, self-contained speaker, and metering of battery voltage, relative received signal strength and power output. Current consumption of the two-meter transceiver is 150 mA on standby and 2.4 amp on transmit. Supply voltage is 11 to 16 Vdc, 13.8 Vdc nominal. Frequency stability is 0.001% from -10 to $+60\,^{\circ}$C.

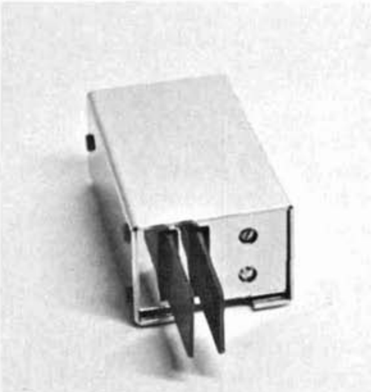
Transmitter power output is 0.8 or 10 watts, depending on setting of hi/lo power switch. Output impedance is 50 ohms nominal. Frequency deviation, internally adjustable to ± 10 kHZ minimum is factory set to ± 7 kHz. Spurious and harmonic responses are attenuated 50 dB below carrier power level. Audio rolloff above 3 kHz at 16 dB per octave.

Receiver sensitivity is 0.4 μV or less for 20-dB quieting. Squelch threshold is 0.2 μV or less; maximum (tight) squelch between 20=dB quieting sensitivity and 20 dB quieting plus 10=dB. Deviation acceptance up to ± 15 kHz. Spurious and image attenuation 65=dB below the desired signal. Adjacent channel selectivity (30-kHz channels) is 60 dB attenuation of adjacent channel. Audio output, 5 watts minimum (with external speaker); audio distortion, 10% maximum at 3 watts output. Priced at $399.95 complete with microphone, built-in speaker and external 2.5 amp alternator whine filter. For more information, write to Standard Communications Corporation, 639 Marine Avenue, Wilmington, California 90744, or use *check-off* on page 94.

ferrite cores

Indiana General CF102-Q3 toroid cores are now available from HAL Devices for $1.25 each. (This core was used in the rf bridge featured in the December, 1970 issue of *ham radio.*) Other ferrite toroids available from HAL are the Indiana General CF102-06, CF102-Q1 and CF101-Q2; these cores are $.50 each. In addition to ferrite cores, HAL Devices carries an interesting line of hard-to-get products for the experimenter, including integrated circuits, hot-carrier diodes, integrated-circuit sockets and Mainline RTTY equipment kits. For more information, use *check-off* on page 94, or write to HAL Devices, Box 365H, Urbana, Illinois 61801.

deluxe permeflex key



James Research has announced a new wider and heavier version of the Permeflex key. The completely enclosed mechanism has independent fiberglass paddles which flex to make contact and have adjustable gap and tension. Additional feet allow the key to be used on its side as a straight hand key. The 8-ampere gold-diffused contacts may be used to key a transmitter directly, or to key the low-level input of an integrated-circuit keyer.

Included with the new deluxe key is an internal bracket and blank printed-circuit board to permit construction of a built-in electronic keyer or monitor. The pre-punched 1/4" holes on the front panel will accommodate subminiature switches and potentiometers. The key is guaranteed for 1 year. $24.95 postpaid in the U. S. A. For more information, write to James Research Company, Department HQ-K, 20 Willits Road, Glen Cove, New York 11542, or use *check-off* on page 94.

alpha-seventy linear amplifier

The Alpha Seventy is a new generation high-power linear amplifier that incorporates many major state-of-the-art advances in design. It easily handles the maximum legal amateur power in any mode without any "on-time" limitations, yet is completely self-contained in a desk-top cabinet. Among the many features of this unique new design is *quiet operation* through the use of vapor-phase

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Other features of the Alpha Seventy include a built-in mosfet electronic T/R switch that is preselected on receive by the extremely high unloaded Q of the plate tank circuit, cutoff bias that is electronically controlled to prevent plate current flow in the absence of rf drive, dc coupled alc output that simplifies tuneup and provision for later installation of an accessory (to be announced) to provide remote-control or automatic band change, tuning and loading.

The Alpha Seventy covers all amateur bands from 80 through 10 meters; a range extension kit for 160 meters is to be announced. Drive requirements are 100 watts PEP nominal for 2.5 kW PEP plate input; 50 watts nominal for 1 kW carrier input. Third-order products are more than 30 dB below each of two equal test tones at 2.5 kW PEP input.

Priced at $1595. For more information, write to Ehrhorn Technological Operations, Inc., Post Office Box 1297, Highway 50 East, Brooksville, Florida 33512 or use *check-off* on page 94.

160-meter antenna tuner

The Top Band Systems model 48MV 160-meter antenna tuner is designed to resonate practically any 40- or 80-meter dipole or inverted vee on 160 meters. The unit covers the entire 160-meter band, and can be used with coaxial cable or open-wire feedline. The tuner will handle 140 watts cw or a-m, or 250 watts PEP ssb. The 48MV Matchverter can also be used to resonate long-wire antennas. $39.95 from Top-Band Systems, 5349 Abbeyfield Street, Long Beach, California 90815, or use *check-off* on page 94.

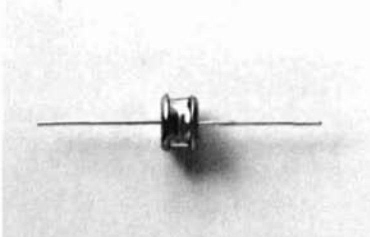
semiconductor cross-reference catalog

Motorola's HEP sales department has announced a new cross-reference and replacement guide, HEP HMA-07, available free through HEP distributors nationwide. This guide cross references more than 25,000 devices to HEP replacements including 1N, 2N, 3N, JEDEC, Japanese, Dutch and other foreign numbers in addition to thousands of manufacturers' regular and special "house" numbers. There is special emphasis on replacement coverage of the device numbers found in consumer products equipment, particularly Japanese merchandise, and several thousand industrial MRO market device types.

This new semiconductor cross-reference guide and catalog includes Motorola's full-line product catalog, which gives the min/max ratings and electrical characteristics for 285 HEP devices, as well as cross-reference information. The Motorola HEP devices are listed by type number with a packaging index, device dimension drawings and selection guide information.

HEP is Motorola's sales program for making semiconductor devices readily available to the experimenter through a nationwide network of authorized suppliers.

surge voltage protectors



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VANGUARD LABS
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lightning, power surges, and other transients, have been developed by Siemens.

The new units, type B2-H10 and B2-H25, have two features of particular advantage to electronic component users and designers: they are only 0.28- and 0.44-inch long, respectively, and provide protection for equipment with peak operating voltages up to 850 and 2000 volts, respectively.

Ultrafast in response, the SVP type B2-H10 has a dc striking voltage of 1000 volts (±15%); for the SVP type B2-H25, the dc striking voltage is 2.5kv. Insulation resistance is greater than 10,000 megohms, 5000 amps rated discharge capability for a 0.3-microsecond wave, and capacitance of less than 2 pF.

The two new SVPs are part of a complete line of surge voltage protectors now being marketed by Siemens. Additional information is available from Siemens Corporation, 186 Wood Avenue South, Iselin, New Jersey 08830, or use *check-off* on page 94.

low-noise uhf transistors

The Nippon Electronic Company has announced a new family of low-noise silicon transistors designed for high-gain applications in the vhf/uhf region below 1000 MHz. These new devices are suitable for broadband amplifiers, rf and i-f preamplifiers, oscillators and digital circuits requiring ultra-fast switching.

The gain-bandwidth product, f_T, for these transistors is typically 3000 MHz; power gain at 500 MHz is typically 25 dB. The 2N5652, with a 1.8 dB typical noise figure at (2.5 dB maximum) 500 MHz, is $11.40; the 2N5651, NF 1.3 dB typical (2.0 dB maximum) at 500 MHz is $25.80; the 2N2650, NF 1.0 dB typical (1.5 dB maximum) at 500 MHz is $53.50. Prices are for small-quantity orders. Units may be purchased from California Eastern Laboratories, Inc., 1540 Gilbreth Road, Burlingame, California 94010. For more information use **check-off** on page 94.

automatic transistor analyzer

Vanguard Electronic Tools has introduced a new automatic transistor analyzer, the model 900, which measures current gain (beta) directly, and measures leakage to the nearest nanoamp. This analyzer, designed for use in or out of the circuit, automatically differentiates between pnp and npn transistors, indicates silicon or germanium, and operates on 115/230 Vac.

Current-gain measurements are zero to 500 (at 20 μA and 200 μA I_B) and zero to 50 (at 200 μA and 2 mA I_B). Leakage can be measured at both I_{CEO} and I_{CBO}. The leakage scale in the 1-μA position has 10 nanoamps per minor division. Collector current is indicated from 10 μA through 100 mA, and the emitter-base voltage drop can be measured to the nearest millivolt.

The in-circuit transistor test is fixed at the 270-ohm shunt level, which means that as long as the test transistor has more than 270 ohms across the junctions, the model 900 will see only the test transistor, and none of the peripheral circuitry.

For qualitative go-no-go testing of transistors and diodes, an audio readout can be activated that will indicate all good transistors and diodes. This is especially helpful when the operator finds it impossible to watch the meter. The price of the automatic transistor analyzer is \$287 (less model 103 electronic probe, which is \$15). For more information, write to Vanguard Electronic Tools, Inc., Hy-Tronix Instruments Division, Post Office Box 667, Newton, Kansas 67114, or use *check-off* on page 94.

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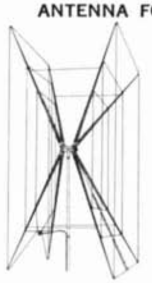

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short circuits

fm receiver

There are several corrections to the fm receiver article that appeared in the September, 1970 issue. Inductors L201, L203, L204 and L205 should use number-24 wire, *not* number 18. Inductors L101 and L102 are Nytronics part number SWD5600. The 22k resistor across T106 can be changed to 100k to facilitate oscillation if T106 has low Q.

Transistor Q204 may not provide sufficient injection to the mixer due to gain differences, manufacturing tolerances, etc. The injection level can be increased by replacing Q204 with a Fairchild SE3005. Be sure to retune T202 and L206 after making the replacement; it may be necessary to add a few more pF across T202 to obtain resonance with the SE3005.

If it is desirable to have a "squelch tail" on your receiver, connect a 10-μF capacitor from the base of Q107 to ground.

QRP indicating wavemeter

In **fig. 1** on page 27 of the December 1970 issue, the 1-mA meter will be zapped if the switch is closed. The battery should be returned to ground through the switch to prevent damage to the instrument.

frequency scaler

On page 28 of the August, 1970 issue the polarity of the electrolytic capacitors are installed backwards; the rectifier bridge is shown correctly. One reader has noted that the photograph shows the electrolytic backwards; this, according to the author, is due to an electrolytic casing being incorrectly installed by the capacitor manufacturer.

inexpensive swr indicator

There are a number of false statements in this article that got by our staff, including misinformation about transmission lines, antenna couplers and impedance matching. If you haven't read this article yet, ignore it; if you have, forget it.

Rf, in coax, flows on the *outside* of the inner conductor, and on the *inside* of the outer braid. There should be no rf on the outside of the outer shield (except at microwave frequencies where the braid leaks). If there is, it is usually caused by pickup from antenna radiation or the fact that an unbalanced line is used to feed a balanced antenna, and rf is coupled directly from the antenna to the outside of the outer braid. This rf sets up parallel standing waves and this is what is detected by the device described in the article. Our staff makes every effort to weed out technical inaccuracies, but we slipped badly on this one, and have re-evaluated our procedures to insure that we don't publish misleading and false information in the future.

BC-1206 conversion

The 500-ohm resistor connected across the 250-pF capacitor in **fig. 1** on page 32 of the October, 1970 issue should be 500 k.

fm frequency meter

The 60-kHz output in **fig. 2**, page 42 of the January, 1971 issue should be connected to the emitter of the 2N2219, *not* the collector.

ST-6 Mainline RTTY demodulator

In **fig. 6**, page 18 of January, 1971 issue, there should be a lead from the input connector to the large dot between R1 and the 620-ohm resistor.

Henry Radio, Inc.
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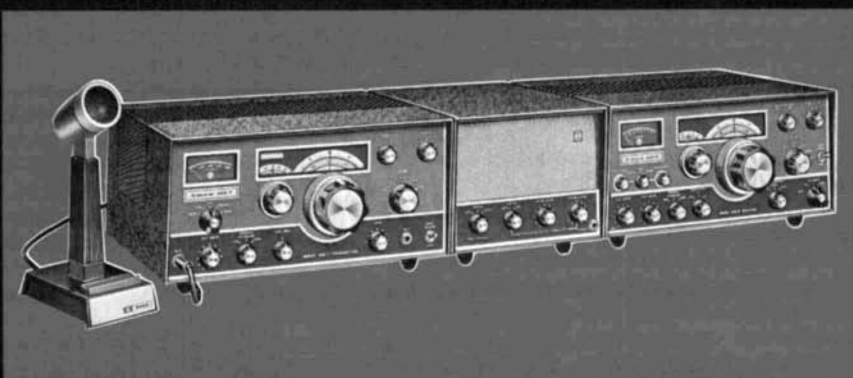
More Details? CHECK—OFF Page 94

introducing



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- Crystal Calibrator with 25 and 100 kc selection.
- Hybrid Design: 7 tubes, 8 transistors, 12 diodes. Transistors used where they provide definite advantage. Tubes used where they still provide superior performance.
- Features Swan's exclusive Single Conversion design, with fewer spurious responses than multi-conversion designs.
- Fully compatible with 600-T transmitter, providing for transceive operation as well as separate frequency control. Also, CW sidetone, and genuine CW break-in operation.
- Built-in AC power supply.
- Dimensions: 15 in. wide, 6½ in. high, 12 in deep.

$395*

600-T SPECIFICATIONS:

- Freq. Range: Full coverage of 10, 15, 20, 40 and 80 meters. Extended frequency coverage for MARS operation with plug-in crystal oscillator accessory, Model 510X.
- Power Rating: 600 watts P.E.P. input. 500 watts CW, 150 watts AM. 100 watts continuous AFSK.
- Pi-Network output for 50 or 75 ohm coax.
- Suppression: Carrier 60 db, unwanted sideband 50 db. Third order distortion approx. 30 db.
- Audio response: Plus or minus 3 db from 300 to 3000 cycles.
- CW Keying: Grid block circuit, Full Break-in system. Includes sidetone to receiver.
- VOX accessory, plug-in.
- Internal AC Power Supply.
- Dimensions: 15 in. wide, 6½ in. high, 12 in. deep.

$495*

600-R ACCESSORIES:

Speaker in matching cabinet **$18***

I.F. Noise Blanker. Installs internally **$79***

Adjustable Audio Notcher. Installs internally **$44***

*Factory price

DRAKE 2-C

Low cost Ham Receiver
GETS "F.B." RATINGS

Hams yak a lot about Drake Gear . . . especially about this great value . . .

Model C-2 Amateur Net **$255.00**

• **Triple Conversion** • **Crystal-controlled First Converter** • **500 kc ranges** for 80, 40, 20, 15 and 10 Meters • **Also any 500 kc range** between 3.0 mc and 30 mc by inserting an accessory Crystal • **Temperature-compensated VFO Tuning** • **Selectable Sidebands** without retuning • **Three Bandwidths**—.4, 2.4, 4.8 kc at 6 db • **Solid-state** Audio, Product and AM Detectors, AVC Amp and Xtal Osc • **AVC Switch** (Fast, Slow and Off) • **SSB, AM and CW** with AVC and S-meter • **Works Break-in CW** with 2-NT Xmtr • **19 Tubes and Semi-Conductors** • **Dimensions:** 11 5/16"W x 6 9/32"H x 9 3/32"D. **Wt.:** 13½ lbs.

ACCESSORIES: 100 KHz Calibrator, Matching Speaker, Noise Blanker, Speaker/Q-Multiplier & Notch Filter, Crystals for other ranges.

Available at your local distributor.

R. L. DRAKE COMPANY

540 Richard Street
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"SOLID-STATE QRP PROJECTS"
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FET Rigs	Xtal & VFO
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¼ & ⅝ Verticals	Low-Band Triangles
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40M TURNSTILE TRIANGLE
DOES A FINE JOB ON 10, 15 and 20 TOO

Parts and Complete Instructions
(does not include mast or line)

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TRIANGLE ANTENNAS
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More Details? CHECK—OFF Page 94

Regency HR-2

AMERICAN MADE

Mobile 2 Meter FM Transceiver

Here is what the 2 meter, FM Ham World has been asking for.

Specifications: 90 day warranty

RECEIVER

The HR-2 receiver is a double conversion, superhetrodyne with highly selective ceramic filter.

Frequency Range	144-148 MHz
Sensitivity	0.35 μv (nom.) 20DB Quieting
Selectivity	6DB Down ± 16KC 50DB Down ± 32KC
Audio Output (3-4 Ω Speaker)	3 Watts 10% Distortion 5 Watts Maximum
Channels	6 Crystal controlled with provision for adding an additional 6 channels
I.F. Frequencies	10.7 MHz & 455KHz

TRANSMITTER

The HR-2 transmitter uses phase modulation for the ultimate in carrier stability. Built in SWR load mismatch circuitry provides protection against open and shorted antenna conditions.

Frequency Range	144-148 MHz
Power Output	10 Watts (min.) @ 13.6 VDC
Modulation	Phase Modulation with automatic deviation limiting
Deviation	Automatic Limiting with internal adjustments from 0-15KC deviation
Microphone	Plug-in, hand held, high Z Ceramic supplied
Channels	6 Crystal controlled with individual trimmer capacitors for Frequency netting

GENERAL

Power Requirements	13.6 Volts (nominal)
Receive (Squelched)	180 MA.
Receive (Max. audio output)	800 MA.
Transmit	2.5 Amps (max.)

STANDARD EQUIPMENT

Built-in 4" Speaker
Mobile Mounting Bracket
SO-239 Antenna Connector Socket
T & R Crystals for 146.94 MHz
PTT Ceramic Mike

only $229^00 Amateur Net

Regency ELECTRONICS, INC.
7900 Pendleton Pike, Indianapolis, Indiana 46226

This is actual size and shape of our radio. Cut it out and place it under your dash to see how compactly it fits.

ALL SOLID-STATE SSB TRANSCEIVER –

$195.00 . .

- Complete single-band SSB transceiver 4 to 5 watts PEP output 15, 20, 40, or 75 mtrs.
- VXO tuning up to 100 KHz or 2 fixed freq.
- Suitable for dry battery operation.
- Light weight, small size makes excellent portable - boat, aircraft, field or mobile.
- Contains 15 transistors, 1 MOSFET, 2 darlington amps., 1 I.C. and 17 diodes. Four-pole filter.
- Some options available to customer requirements.
- Furnished with spare switching and final amp. transistors, dummy load and extra plug.

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Entire staff consists of licensed hams who are instructors in electrical engineerng in some of our finest colleges and universities. Camp opens July 31st and closes August 14th. Tuition of $200.00 includes all camp expenses: room, meals, notebooks, textbooks, and insurance. Send for our brochure.

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General Secretary
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Please send me the Booklet and Application Blank for the Camp Albert Butler Radio Session.

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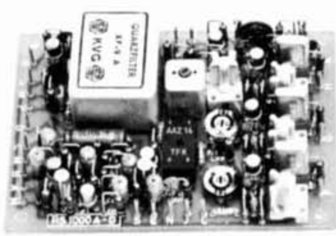

9 MHZ EXCITER for SSB, AM, FM, CW and RTTY

Three independent, electronically switchable crystal oscillators operating at 9001.5 kHz (LSB), 8998.5 kHz (USB) and 9000.0 kHz (carirer frequency) for AM, FM, CW and RTTY. Carrier oscillator includes varactor diode circuitry for frequency modulation and teletype frequency shift keying. Diode-quad ring modulator for SSB. Crystal filter with two amplifiers. Separate, three-stage microphone amplifier provides audio for SSB and FM modulators, and for external VOX unit (HS 1000 S). HS 1000 C intended for transmitters, HS 1000 D for transceivers (contains steep-skirt crystal filter which can be switched into I.F. chain in "Receive").

HS 1000 D (transceiver exciter) **$85.53**
HS 1000 C (transmitter exciter) **$73.15**

VOX/ANTI-TRIP MODULE

Complete VOX unit PTT override and anti-trip provision.

HS 1000 S **$17.60**

9 MHZ I.F. AMPLIFIER-DEMODULATOR

Three I.F. amplifiers (two of which are AGC controlled), an AM detector, an FET product detector, and a three-stage AGC amplifier with S-meter output. The AGC amplifier and S-meter also serve for transmitter output indication. Matching crystal filters available.

HS 1000 Z **$28.60**

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1.4 Watt output audio amplifier for receiver or low-level modulator. (Matches HS 1000 Z.)

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Also: VHF/UHF converters and transverters, KVG 9 and 10.7 MHz crystal filters.

AVAILABLE FROM STOCK!

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ANNOUNCING!

The FIRST AM-FM Transceiver for 2 Meters

The All Solid State CTR-144 by COMCRAFT

FEATURES:

- ☐ All solid state — no tubes
- ☐ Built-in VFO
- ☐ AM and FM transmit both crystal and VFO
- ☐ Separate receiver and VFO tuning
- ☐ Four transmit crystal positions (8 MHz)
- ☐ Double conversion receiver
- ☐ Crystal controlled first conversion
- ☐ MOS FET receiver front end
- ☐ Built-in AC power supply
- ☐ Push-to-talk
- ☐ 12 watt input — 6 watt output
- ☐ Battery portable (optional rechargeable battery pack)
- ☐ Built-in squelch and ANL
- ☐ High level transmitter modulation on AM

$389.95 SHIPPED POSTPAID*

PRICE INCLUDES 146.94 MHz CRYSTAL

SPECIFICATIONS

RECEIVER	Frequency Coverage	143.8 to 148.1 MHz
	IF Bandwidth	18 kHz
	Noise Figure	4 dB nominal
	Image Rejection (Aircraft band)	80 dB
TRANSMITTER	Frequency Coverage	143.8 to 148.1 MHz
	No. of crystal sockets	3(internal) 1(external)
	Crystal Frequency	Transmitter frequency divided by 18 (8.000 to 8.222 MHz)
	Power Input	12 watts
	Power Output	6 watts
	VFO Coverage	144 to 148 MHz
	Modes	AM and FM
	FM Deviation	Up to 10 kHz
DIMENSIONS	10¼" W x 6¼" H x 7½" D	

* U. S. ONLY

THE CTR-144 IS AVAILABLE
FACTORY DIRECT FROM:

COMCRAFT COMPANY
P. O. Box 266 — Goleta, Calif 93017

COMCRAFT COMPANY
P. O. BOX 266 — GOLETA, CALIF 93017

☐ I enclose $389.95. Please send me a CTR-144.
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Calif. residents add 5% sales tax.
☐ Please send me an illustrated brochure and accessory list.

FROM: NAME ______________________

STREET ______________________

CITY ____________ STATE ____________ ZIP ______

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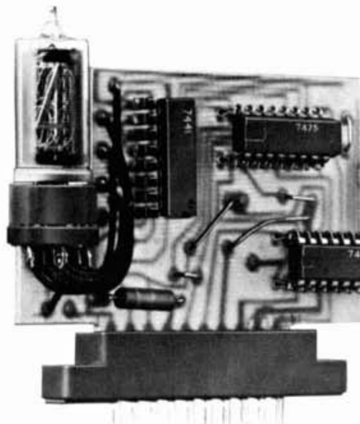
NIXIE READ OUT STAGE

"NEW TTL LOGIC"

AT A LOW LOW PRICE

$12.49 *see price schedule below



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BASIC KIT NX100

NL 940S nixie read out tube
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7490 Decade
7441 Decoder/driver
Resistor
Etched and Drilled glass epoxy P.C. board

NX100-Q SAME AS NX 100 WITH ADDITIONAL QUADLATCH

DELUX KIT NX101

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NL 940S tube socket
7490 Decade
7441 Decoder/driver
Resistor
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7475 Quad Latch
2 - 16 Pin I.C. socket assembly
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PLEASE ORDER BY KIT NUMBER

QUANTITY	NX100	NX100-Q*	NX101
1 - 3	$14.45	$16.75	$18.95
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10 - up	12.49	14.75	16.45

*WITH QUAD LATCH
Completely guaranteed

NX 101 NIXIE READ OUT STAGE TTL LOGIC

ALL BOARDS DIVIDE BY 10 OR DIVIDE BY 6

READ OUT STAGE SPECIFICATIONS

- NL 940s Read Out Tube with two decimal points supplied. (or equivalent).
- 2 x 3 etched and drilled glass epoxy printed circuit board.
- Accepts 10 pin PC board connector
- Voltage requirements 5 volts DC 80 ma for integrated circuits, 170 to 300 volts DC at 2 ma for the read out tube.
- 3TTL INTEGRATED CIRCUITS
- 7490 Decade supplies a BCD code output
- 7475 Quadlatch stores the count while the decade is re-counting not used in digital clocks (when quad latch is not used jumpers are required).
- 7441 Decoder Driver converts the BCD code to ten different signals needed to drive the read out tube.

BY INTERCHANGING OF 3 JUMPERS THE P.C. BOARD IS ADAPTABLE TO DIVIDE BY 6 OR DIVIDE BY 10.

R & R ELECTRONICS
311 EAST SOUTH ST.
Indianapolis, Ind. 46225

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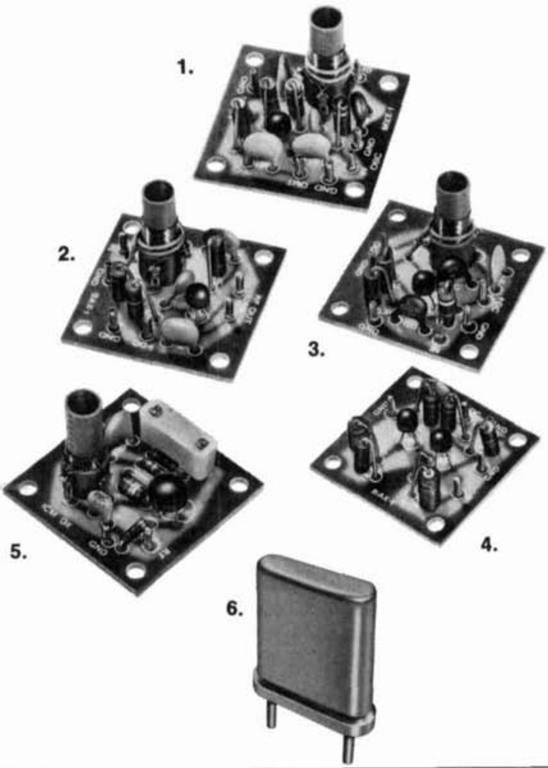
for the experimenter!

INTERNATIONAL EX CRYSTAL & EX KITS

OSCILLATOR • RF MIXER • RF AMPLIFIER • POWER AMPLIFIER



1. MXX-1 TRANSISTOR RF MIXER

A single tuned circuit intended for signal conversion in the 3 to 170 MHz range. Harmonics of the OX oscillator are used for injection in the 60 to 170 MHz range. Lo Kit 3 to 20 MHz, Hi Kit 20 to 170 MHz (Specify when ordering)........................**$3.50**

2. SAX-1 TRANSISTOR RF AMP

A small signal amplifier to drive MXX-1 mixer. Single tuned input and link output. Lo Kit 3 to 20 MHz, Hi Kit 20 to 170 MHz (Specify when ordering)........................**$3.50**

3. PAX-1 TRANSISTOR RF POWER AMP

A single tuned output amplifier designed to follow the OX oscillator. Outputs up to 200 mw, depending on the frequency and voltage. Amplifier can be amplitude modulated. Frequency 3,000 to 30,000 KHz..**$3.75**

4. BAX-1 BROADBAND AMP

General purpose unit which may be used as a tuned or untuned amplifier in RF and audio applications 20 Hz to 150 MHz. Provides 6 to 30 db gain. Ideal for SWL, Experimenter or Amateur........................**$3.75**

5. OX OSCILLATOR

Crystal controlled transistor type. Lo Kit 3,000 to 19,999 KHz, Hi Kit 20,000 to 60,000 KHz. (Specify when ordering)................**$2.95**

6. TYPE EX CRYSTAL

Available from 3,000 to 60,000 KHz. Supplied only in HC 6/U holder. Calibration is ± .02% when operated in International OX circuit or its equivalent. (Specify frequency) **$3.95**

for the commercial user

INTERNATIONAL PRECISION RADIO CRYSTALS

International Crystals are available from 70 KHz to 160 MHz in a wide variety of holders. Crystals for use in military equipment can be supplied to meet specifications MIL-C-3098E.

CRYSTAL TYPES:
(GP) for "General Purpose" applications
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(HA) for "High Accuracy" close temperature tolerance requirements.

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INTERNATIONAL

CRYSTAL MFG. CO., INC.
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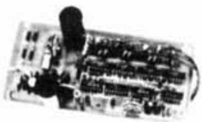
HAL DEVICES

HAL 311BC ELECTRONIC KEYER $53.00

THE most versatile keyer available.
Send for full details on the **HAL 311BC** and the complete line of **HAL** electronic keyers. There is a model to fit your requirement and budget from $16.50 to $53.00. Shipping extra.
Now available in kit form for even greater value.



HAL TOUCHCODER II KIT $55.00

Complete parts kit, excluding keyboard, for the W4UX CW code typer. All circuitry on one 3 x 6" G10 glass PC board. Plug-in IC sockets. Optional FM repeater ID, contest ID, and RTTY features available. Keyboard $25.00. Shipping extra. Write for full details.

HAL DIP BREADBOARD CARD

Drilled G10 glass PC board accepts 6 16 pin DIP IC's in plug-in sockets. Each IC pin fanned out to two pads. Plugs into standard 22 pin edge connector (.156" finger spacing). $5.50

DOUBLE BALANCED MODULATOR KIT

For the DBM in March 1970 Ham Radio
7/8 x 2" drilled G10 glass PC board
4 HP-2800 hot carrier diodes matched by **HAL**.
2 Indiana General CF102-Q1 toroids.
Wire and instructions included. $6.50

DIGITAL TTL

7400 4 - 2 input NAND	.65	7441 4 - 10 line decoder/Nixie Driver	3.90
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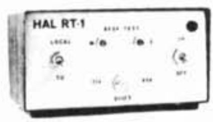
7402 4 - 2 input NOR	.65	7472 1 - MS J-K FF	1.20
7404 6 - inverter	.75	7473 2 - MS J-K FF	1.40
7405 6 - inverter, open col.	.75	7475 4 - latch	2.75
7410 3 - 3 input NAND	.65	7490 Decade counter	2.50
7420 2 - 4 input NAND	.65	7493 4 bit binary counter	3.50
7430 1 - 8 input NAND	.65	7495 4 bit L-R shift register	4.00
7440 2 - 4 input Buffer	.75		

Hot Carrier Diodes: HP2800. . . . . 90¢, 12/$10.00 Matched by **HAL** . . . . 4/$4.25

IC's: f μ L 900, 914. . . . . .60¢ f μ L 923. . . . . .90¢
MRTL MC790P, MC890P . . . . $2.00, 10/$19.50
MC724P, MC789P, MC792P, MC725P . . . . .$1.05, 10/$9.50
Also available: MC723P, MC788P, MC880P, MC767P, MC9760P.
OP AMP: SN72709N (DIP), SN72709L (TO-5), ...$1.25
TOROIDS: Indiana General CF102-06, CF102-Q1, CF101-Q2, ... 50¢
CINCH IC sockets, 14-DIP, 8-ICS. . . . . .60¢ **HAL DEVICES**
Add 50¢ Postage, send for complete list. Box 365 Urbana, Illinois 61801

HAL MAINLINE ST-6 RTTY TU

Complete parts kit for the W6FFC ST-6 now includes all parts except cabinet. Only 7 **HAL** circuit boards (drilled G10 glass) for all features. Plug-in IC sockets. Custom transformer by Thordarson for both supplies, 115/230V, 50-60Hz. $135.00 kit. Wired units available. Shipping extra. Write for details.



HAL RT-1 TU/AFSK KIT $51.50

All TU and AFSK generator circuitry, including PS, on 3x6" G10 PC board. 850, 170, and CW ID shifts. Zener protected transistor loop switch. High and low impedance audio output. Price $45.00. Shipping extra. Write for full details.
HAL Designer Cabinet for the above $6.50.
3 pole Butterworth filter drilled PC board $3.00.

HAL MAINLINE ST-5 RTTY TU

ST-5 kit now includes drilled G10 glass boards, custom Thordarson transformer, meter and metering components. Boards accept both round and DIP 709 IC's. $50.00. Less boards, meter & meter components $37.50. Boards only $6.00. Shipping extra.

HAL MAINLINE AK-1 AFSK OSC

HAL now offers a parts kit for the AK-1 AFSK osc. Drilled G10 glass PC board plugs into 12 pin edge connector for compatibility with the **HAL** ST-6, or for ease of use alone. Requires 12vdc. $27.50. Shipping extra. Write for parts list.

HAL ID-1 FM REPEATER IDENTIFIER $70.00 Kit Form

TTL logic. Power line frequency counter for 3 minute or less timing and control. Easily reprogrammable diode ROM uses only 27 diodes (depending on call) to send DE "any call". Low impedance audio with volume and tone control. All circuitry including PS on small G10 glass PC board. Write for full details.

ORDERING INFORMATION

Postage is not included in the prices of **HAL** products. Please add 50¢ on small parts orders, and $2.00 on larger kits. Shipping is via UPS when possible, and via insured parcel post otherwise. Please give a street address.

HAL DEVICES, Box 365H, Urbana, Il 61801

More Details? CHECK–OFF Page 94

flea market

RATES Commercial Ads 25¢ per word; non-commercial ads 10¢ per word payable in advance. No cash discounts or agency commissions allowed.

COPY No special layout or arrangements available. Material should be typewritten or clearly printed and must include full name and address. We reserve the right to reject unsuitable copy. **Ham Radio** can not check out each advertiser and thus cannot be held responsible for claims made. Liability for correctness of material limited to corrected ad in next available issue. Deadline is 15th of second preceding month.

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

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HRO-60. "B" slicer, manuals, A,B,C,D,AC coils and case, headphones, some spare tubes, excellent condition, $230 or best offer; Adventurer, 8 40m. xtals, 6 position xtal switch, $35, best offer. You ship. Jon Ahlquist, 204 Bender, University of Northern Iowa, Cedar Falls, Iowa 50613.

THE NOVICE *Newsletter. Free sample, 1240 21st* St., Hermosa Beach, Calif. 90254.

NEEDED - DRAKE AC-3 or AC-4 power supply for TR-4. Contact Dave Flinn, 10 Graham Road West, Ithaca 14850. 607-257-1575.

EXCLUSIVELY HAM TELETYPE 19th year, RTTY JOURNAL, *articles*, news, DX, VHF, classified ads. Sample 30¢. $3.00 year. Box 837, Royal Oak, Michigan 48068.

TELETYPE — Parts (fast service), machines, all models. Buy all parts, late machines. S.A.S.E. list. Typetronics, Box 8873, Ft. Lauderdale, Fla. 33310. W4NYF.

CONNECTICUT HAMS: Come and see all the goodies at Roger S. Miner, Surplus Electronics, 246 Naugatuck Ave., Milford, Conn. 06460. Tel. 877-0555.

TRI-EX THD-354 54′ crank-up tower, $50. Dick Yerian, WB8HTA/4, 6709 Greendale Rd., Alexandria, Virginia 22310.

FOR SALE several good used TV cameras all transistor $125.00 each, send sase for more information. Don Heringhaus WA8ZRZ, RR#1, Box 77, Ottawa, Ohio 45875.

VIRGINIA STATE ARRL CONVENTION - May 22-23. War Memorial Building, Vinton, Va., Rt. 24 (off 460 *in Roanoke County*). *Saturday* 6:00 p.m. registration and social. 8:30 p.m. firstnighter Round & Square Dance. Figures by Andy Anderson, music by the Top Notches. Free Western Square Dance demonstration. Casual or western dress please. Sunday 7:00 a.m. registration and free Continental breakfast. Largest Flea Market held in the Roanoke Division. All dealers invited. No fees. Contest - Homebrew - Mobilerig QSL - Leftfoot Sending. Picnic area - playground - lunch - displays - traffic session. Guest speaker: Joe Galeski, W4IMR. Registration $1.50 ea., 4 for $5.00. Write: Roanoke Valley ARC, Van Wimmer, Rt. 4, Box 446, Salem, Virginia 24153.

NEW JERSEY'S LARGEST HAMFEST May 2 sponsored by the Key Klickers of Stirling. Doors open 8:00 a.m. Admission $1. All the gear you can fit on an 8 ft. table for $3. Held at Passaic Township Youth Center, Stirling. For information call or write Ron Mills, 413 Elm Street, Stirling, NJ 07980. 201-647-1283.

"HOSS TRADER ED MOORY" says he will not be undersold on Cash Deal! SHOP around for your best price and then call or write the "HOSS" before you buy! NEW EQUIPMENT: New "Demo" Galaxy GT-550 *with warranty, $395.00: New Rohn 50 Ft.* Foldover Tower prepaid, $219.00: New Mosley Classic 33 and Demo Ham-M Rotor, $205.00: USED EQUIPMENT: Collins 312B-4 Console, $135.00: Drake TR-4, late serial, $449.00: R4-B, $349.00: T4-XB, $365.00: SPR-4, $369.00: Ham-M Rotor, $85.00: Swan 250 (6 meter), $219.00: SB-34, $249.00: WE HAVE ALL NEW Drake, Galaxy, Ty-*Meter Clocks, Varitronics, Regency HR-2, and* **much more:** Moory Electronics Co., P. O. Box 506, Dewitt, Arkansas 72042. Phone (501) 946-2820.

AM SIGNAL GENERATORS: AN/URM-25D; 10 khz to 50 mhz; Internal Modulation; Crystal Calibrator; Precision RF Attenuator; RF output and percent of modulation metered. Reconditioned and aligned. With cover and accessories $170; Generator only $150. Brochure offering other Test Equipment available. James Walter, 2697 Nickel, San Pablo, California 94806.

FOR SALE: Squires-Sanders SS-1R, SS-1S, SS-1RS (all new), $550. SX-115 (mint), $275. 75S3-A, 0.2 crystal, 2.1 and 3.1 mechanical filters, immaculate, $450. KWM-2A #18922, Noise Blanker, 516F-2, $950. 32S-3 #101,493, 516F2, $725. MP-1 or 516-EI d. c. supplies for Collins, $100. 351D-2, $100. SR-150, PS150AC, PS150DC, $325. Galaxy-300, PSA-300 p. s./spkr console, $185. Waters Nuverter (6 & 2 nuvistor converter), $100. Viking Thunderbolt, $250. Motorola 30-D, complete, crystalled on 525/640, $75. TA-33 (new), $120. Telex headset (new), $5. TR-44 (new), $55. Filter F455Y60, (new), $20. F455FA-15 (for 75S3-B), $50. Messenger III, a.c. supply, $100. Collins 302C-3 wattmeter, $75. Lambda VR supplies, $25 (write for specs). Clegg 66'er, $125. KWM-1, 516F-1, a.c. and d.c. supplies, mobile mount, $325. Capacitors, 4 mfd/10 KV, $15. Transformers: 5VCT/30A, 6.3VCT/20A, $8. SB-200, spare P. A.'s, $215. SR-500, PS500AC, PS500DC, $350. GR-1800A VTVM, $50. 312B-5, cables, $275. WANT: 4CX-1000A (heat-sealed bags only!). HT-32-B. 30L-1 *(latest series).* 312B-4. 75S-1 (over 10,000). 75S3-B. James W. Craig, W1FBG, 29 Sherburne Ave., Portsmouth, N. H. 03801. 603-436-9062.

HOOSIER ELECTRONICS Authorized dealers for Drake, Hy-Gain, Ten-Tec, Galaxy, Regency, Hallicrafters. All equipment new and fully guaranteed. Write today for our low quote. Hoosier Electronics, R.R. 25, Box 403, Terre Haute, Indiana 47802.

JOHNSON RANGER 2 (L160-6m) excellent condx $120 plus shipping. R. Walls, 305 Caroldale Lane, Middletown, Kentucky 40243.

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

SELL: VIKING VALIANT $110. Wanted: 30L1, Gordon Girton, 1192 Ayala, Sunnyvale, Calif. 94086.

QSO's EN ESPANOL and auf Deutsch on tapes and cassettes. 1¼ hour Spanish course $11.95, 1½ hour German course $13.95. Manuals only, $2.50 each. FOREIGN LANGUAGE QSO's, Box 53, Acton, Mass. 01720.

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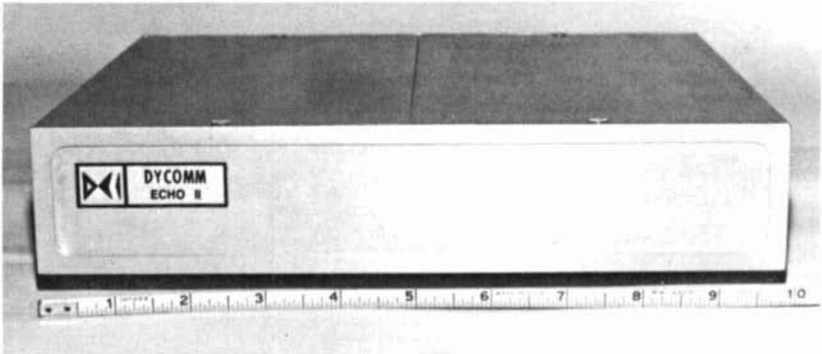

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More Details? CHECK–OFF Page 94

COLLECTORS: Have old electronic tubes for sale. Send self-addressed envelope for list. Physics Department, Middletown High, 601 N. Breiel, Middletown, Ohio 45042.

SELL OR TRADE 6 & 2 equipment, 8 ele. 6 mtr beam, 15 ele. 2 mtr beam, 72′ crank up tower $150. 4 Motorola FM rigs on 52.525 & 64 with solid state supplies $175. 2 mtr 100 watt FM rig on 146.76 $95. 6 mtr SSB Clegg Venus $175. 21KW, 1% line regulator, 230 VAC $75. Need high power mobile transceiver and P.S. for 80-20 mtr. Evenings only, phone 213-444-1531, Parks Squyres.

PARAMETRIC AMPLIFIER CIRCULATOR 220mc $45; 432mc $55; TWT Amplifier w/power 1296mc $45; list few additional paramp components SASE. W4API, Box 4095, Arlington, Virginia 22204.

WANTED USM-1G/SG-47, state price and condition. W7JBY, 515 Birch St., McMinnville, Ore. 97128.

SWAN 350C TRANSCEIVER 550 watts CW/SSB with calibrator, excellent condition, $400. Gary Jordan, WA6TKT, 629 Manhattan Avenue, Hermosa Beach, California. Includes 117XC power supply!

MOTOROLA HT-100 Fantastic new unit used but a few months. 2 freq. .94-.94 & .28-.88, complete with charger $375.00. E. Agoston, K8TTC, 11535 Dunham Road, Northfield, Ohio 44067.

THE FIFTH ROCK RIVER HAMVENTION will be presented by the Rock River R C of Dixon, IL on May 16, from 9:00 a.m. to 5:00 p.m. at the Lee County 4H Center, Amboy, IL which is located one half mile east of the Intersection of Highway 52 and 30. We have the concrete floor buildings under contract this year, so no dust problem this year. Advanced tickets $1.50, at the door $2.00. Plenty of parking and food. Plenty of tables, all under roof. Campers welcome. Talk in frequency is 3.950 and 50.4 MHz. For tickets send check or money order to Carl Karlson, W9ECF, Nachusa, IL 61057.

SYRACUSE, NY HAMFEST — April 17, at Song Mountain off Interstate 81, Exit 14. Flea market, contests, speakers, NET meetings. Tickets $5.50 in advance, $6.50 at door. R.A.G.S., Box 88, Liverpool, NY 13088.

"I LOVE THE BANJO" my latest Stereo LP. 36 tunes Dixie to Classics Banjo Solo $4.95 PP. RICHELIEU, The Banjo Man, W9JS, 215 S. Washington, Wheaton, Ill. 60187.

MANUALS — $6.50 each: R-390/URR, R-390A/URR, BC-639A, URM-25D, CV-591A/URR, TS-497B/URR, BC-348JNQ, TS-587B/U, BC-779B, TS-186D/UP, USM-24C, SP-600JX, FR-5/U, OS-8C/U. S. Consalvo, 4905 Roanne Drive, Washington, DC 20021.

WANTED: 500KC MECHANICAL FILTERS for Collins R-388. One, two, or three KC bandwidths. Art Moore, W2MJD, 32 Morton Pl., North Arlington New Jersey 07032.

STOLEN from University of Akron Amateur Radio Club: Collins 32S-3 #102358, 75S-3C #11863, 30-L1 no. not available, 321B-4 #52245, 516F-2 #19064. Swan 250C #E211312, 117XC #016891, TV-2B #T149805. Heathkit SB610 #8331512A. Sony 260 Stereo Tape Recorder, Vibroplex-speed Key. Brown model CTL Keyer Paddles. Reward for recovery and/or information leading to arrest and conviction. Akron, Ohio Police Department, AC216-375-2181.

ORIGINAL EZ-IN DOUBLE HOLDERS display 20 cards in plastic, 3 for $1.00, 10 for $3.00 prepaid. Guaranteed. Patented. Free sample to dealers. Tepabco, John K4NMT, Box 198R, Gallatin, Tenn. 37066.

ASK FOR FREE LIST of used Ham gear or for prompt personal attention on any new gear. Mail your order direct to VanSickle Radio, W9KJF, Indianapolis, Indiana 46205. 40 years experience.

CODE PRACTICE TAPES - Novice - General - Extra Class - Specify - $8.00 each. W9CJJ, 1105 Schaumburg Road, Schaumburg, Illinois.

WANTED R390, R390A, R389, 51J4, 51S1, Racal, Nems, Clarke, Marconi receivers. SWRC, P. O. Box 10048, Kansas City, Missouri 64111.

VHF NOISE BLANKER — See Westcom ad in Nov., Dec. '70 and Mar. '71 Ham Radio.

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More Details? CHECK–OFF Page 94

THE BATON ROUGE AMATEUR RADIO CLUB will hold their Annual Ham Fest in Baton Rouge, Louisiana on the first weekend in May. Hospitality Room Saturday at 1:00 p.m. at the Holiday Inn-South followed by a supper and dance at the same location. Sunday, May 2nd, a barbecue lunch, along with swap tables, auctioning, and raffling of door prizes will be held at the United Commercial Travelers Camp one mile east of Baton Rouge on Highway 1_0. The top door prize will be a SB-220 linear amplifier. For more details contact WA5OLU.

TOROIDS! Lowest price anywhere. 40/$10.00 POSTPAID (5/$2.00). center tapped, 44 or 88mhy. 32KSR page printer, reconditioned, perfect $225. MITE UGC41KSR page printer, reconditioned, $250. Mod28 Sprocket to friction kit, $25. 28LBXD TD, $70. 28LPR reperf with gear shift, $170. Model 15KSR, $65. Matching RA87P.S. Unused, $7. *Lorenz* 15KSR, $75. *Sync motors*, $7. 14TD, $20. DPE punch, $14. HP200CD Oscillator, $95. R390/URR, $550. 11/16″ tape, 40/$10.00. 33ASR, complete, $700. Stamp for listing. Van W2DLT, 302H Passaic, Stirling, N. J. 07980.

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

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

TELETYPE #28 LRXB4 reperforator-transmitter "as is" $100; checked out $175. Includes two 3-speed gearshifts. Alltronics-Howard Co., Box 19, Boston, Mass. 02101. 617-742-0048.

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IMPORTANT — ROCHESTER location for W.N.Y. Hamfest and VHF Conference, May 15th, has been changed. Send for map and program. Write WNY Hamfest, Box 1388, Rochester, N. Y. 14603.

NOVICE CRYSTALS: 40-15M $1.38, 80M $1.83. Free flyer. Nat Stinnette Electronics, Umatilla, Florida 32784.

THE ONLY AUTHORITATIVE QRPP handbook: The Milliwatt: National Journal of QRPP. 125 pages, 10 QRPP transmitters, 2 receivers, accessories; Operating News, Log Selections, QRPP WAS/DXCC standings; articles on technical subjects for the QRPP operator. Volume I, $4.00. SASE for table of contents. Ade Weis, K8EEG/O, The Milliwatt, Meckling, SD 57044.

THE SPRING AUCTION OF THE ROCKAWAY ARC will take place Friday evening April 23, 1971 at 8:00 p.m. at the American Irish Hall, Beach Channel Drive at Beach 81st St., Rockaway Beach, N. Y. Come to the best auction in the New York Area. For further info write to Al Smith, WA2TAO, Auction Chairman, P. O. Box 341, Lynbrook, N. Y. 11563.

SETH THOMAS DIGITAL CLOCKS with seconds indication reg. $27.95 value only $13.95 postpaid while they last. Laboratory clear, for sale or trade: Singer Meterics Spectrum Analyzer SPA#3 200CPS-15MC R/mount $800.00 new cost $3500.00, HP520A 10 MC scaler R/mount $75.00, GR805C sig. gen. *500KC-50MC cal. output $250.00, ME74/U* AC VTVM like new $50.00, TS375A/U AC-DC VTVM like new $50.00, SP 600 JX rec. 500KC-54MC retubed recal. our lab. $275.00, manuals are included all units. Want HP608D,E,F, or 390A series rec. Wawasee Electronics Co., P. O. Box 36, Syracuse, Indiana 46567.

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WORLD QSL BUREAU — See ad page 92.

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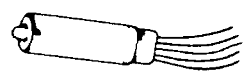

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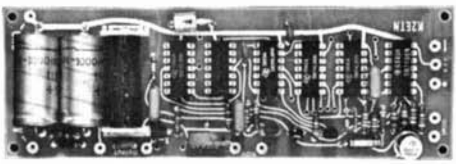

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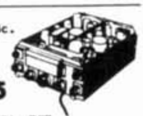

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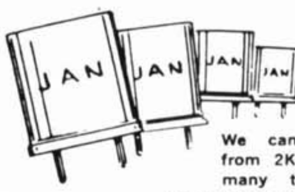

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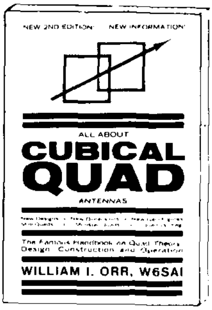

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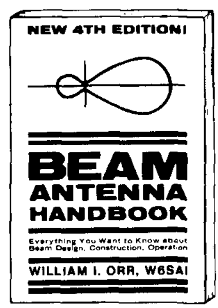

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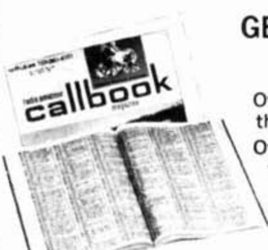

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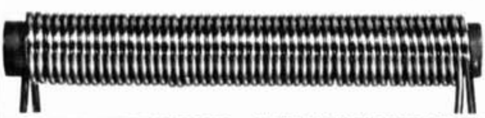

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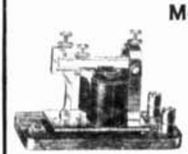

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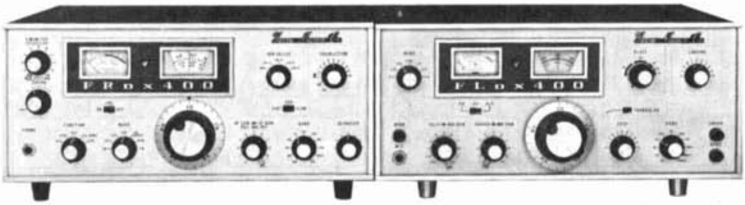

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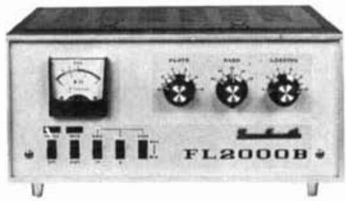

FL2000 B Linear Amplifier.

Ideal companion to the Series 400, this hand-crafted linear is another example of Yaesu's unbeatable combination of high quality and low cost. Designed to operate at 1500 watts PEP SSB and 1000 watts CW, this unit provides superb regulation — achieved by a filter system with 28 UF effective capacity.

Other features include dual cooling fans (one for each tube), individual tuned input coils on each band for maximum efficiency and low distortion, and a final amplifier of the grounded grid type using two rugged carbon-plate 572 B tubes. Ready to operate at only $299.95.

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The suitcase Yaesu.

Next time you hit the road, take the world with you.

That means taking the FT-101 with you. The solid-state portable rig that fits in a suitcase. 260 W PEP, 180 W CW and 80 W AM maximum input power, 0.3 microvolts receiving sensitivity for 10 db signal-to-noise ratio . . . in a thirty-pound package that even includes built-in 12 VDC and 117 VAC power supplies.

Whether you're cruising a turnpike or weekending in a mountain cabin, all you need is 12 VDC, or 117 VAC and an antenna to work the world via any band from 80 meters through 10 meters.

10 FET's, 3 IC's, 31 silicon transistors, and 38 silicon diodes and computer-type plug-in modules make it all happen. Add to that a built-in VOX, 25 KHz and 100 KHz calibrators, the WWV 10 MHz band, a high Q permeability tuned RF stage, and a ±5 KHz clarifier. These considerations mean home base type operation no matter how far you are away from home.

For in-car operation, there's a built-in noise blanker — to pick out noise spikes, leaving behind only clean signal copy.

About those plug-in modules — if one of them ever should give you trouble, just send it in to us and we'll rush you a new card by return mail. The Yaesu FT-101 is guaranteed fully for one year.

Want to get away from it all? Get away with the FT-101. And keep the world in a suitcase. Only $499.95.*

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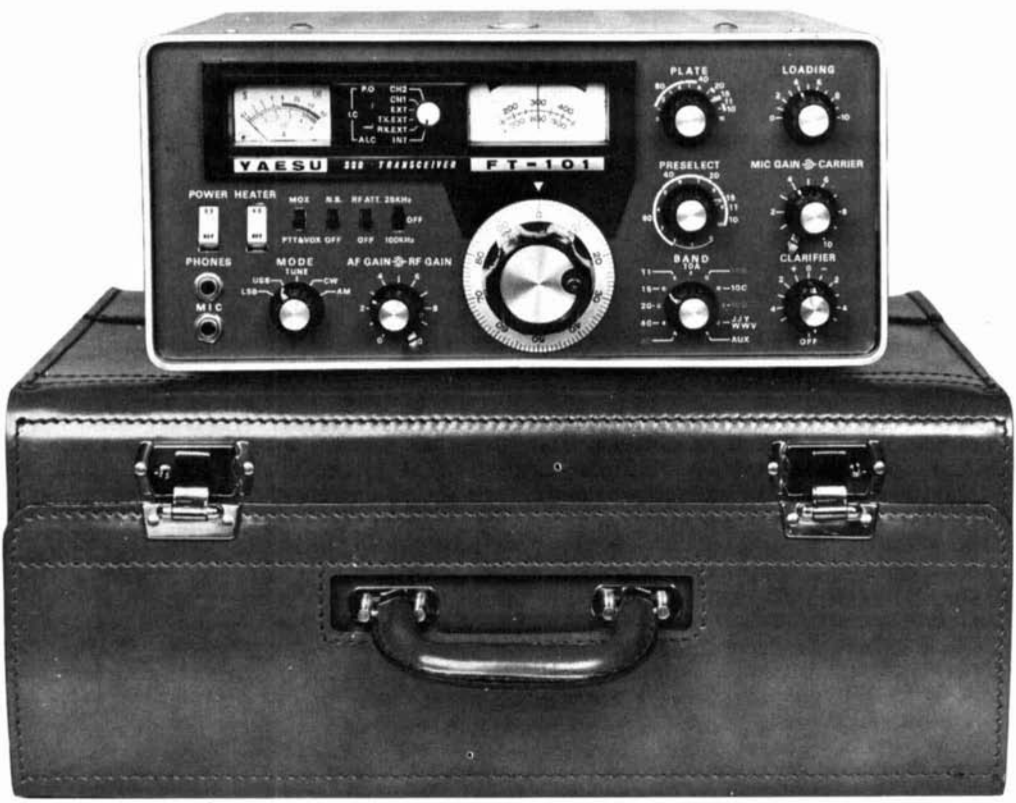


*Suitcase not included

More Details? CHECK—OFF Page 94

For $450, you just can't beat the Yaesu FTdx 560.

You can't even beat it for $800.

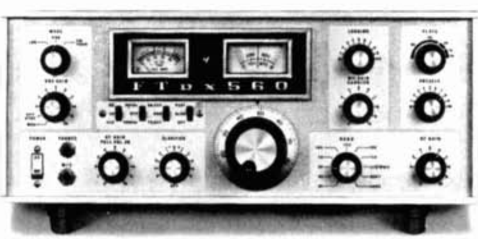
How come the Yaesu is such a good deal?

First of all, it's made in Japan, where people do painstaking electronic assembly work for a lot less money than they do in the U.S. Secondly, it's probably the highest quality transceiver made anywhere in the world, regardless of cost.

Also we import the Yaesu and sell it direct to you, eliminating the usual dealer profit.

The Yaesu FTdx 560 is a fully assembled, fully guaranteed transceiver with 560 watts PEP of SSB power, 500 CW. Included in the selling price are many of the things you usually have to pay extra for. Like power supply, WWV, calibrators, VOX and the one-year warranty. And a lot more.

To see how much more you get with Yaesu, send for our new information packet. It includes things like a chart and photos that compare Yaesu and Yaesu workmanship with other transceivers, plus a complete schematic. Study this packet and you'll see right away how much more value there is in a Yaesu.



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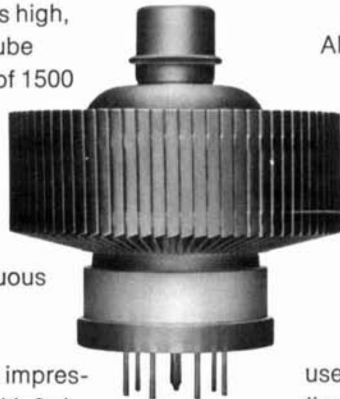
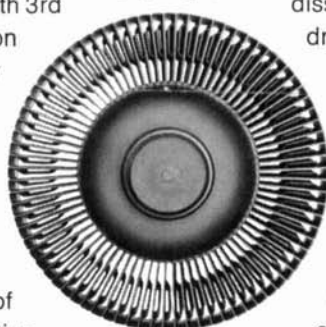
EIMAC's new 8877 high-mu triode delivers over 1500 watts output at 220 MHz. (2000 watts output at 30 MHz is easy)

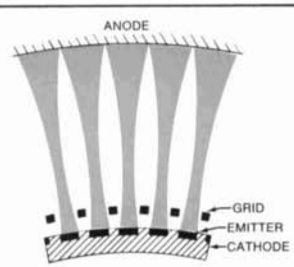
On your right is the new, rugged, ceramic/metal 8877 high-mu power triode by EIMAC. Another state-of-the-art tube. Only three and one-half inches high, this low-profile, heavy-duty tube has a plate dissipation rating of 1500 watts, a maximum plate voltage rating of 4000 and a maximum plate current rating of one ampere. In the HF region, typically, the 8877 coasts along at a continuous duty level of 3500 watts PEP input. A peak drive signal of only 65 watts is required. This impressive power gain is achieved with 3rd order intermodulation distortion products −38 decibels below one tone of a two equal-tone drive signal.





This magnificent power triode is rated at full input to 250 MHz. The low impedance grid structure is terminated in a contact ring about the base of the tube, permitting very effective intrastage isolation to be achieved up to the outer frequency limit of operation. The close tolerance grid, moreover, is composed of aligned, rectangular bars to achieve maximum grid dissipation and controlled transconductance. This aligned grid, plus the EIMAC segmented, self-focusing cathode provide low grid interception and the low grid drive requirement; both of paramount importance in the VHF region. Although primarily designed for superlative linear amplifier service demanding low intermodulation distortion, the 8877's high efficiency permits effective operation as a class C power amplifier or oscillator, or as a plate modulated amplifier. The zero bias characteristic is useful for these services, as plate dissipation is held to a safe level if drive power fails, up to an anode potential of 3 kV.

The sophisticated circuit connoisseur will appreciate the many advantages of this newly developed power tube. Write for detailed information. And remember —the 8877 is another example of EIMAC's ability to provide tomorrow's power tube today. For additional information on this or other products, contact EIMAC, 301 Industrial Way, San Carlos, California 94070. Phone (415) 592-1221 (or call the nearest Varian/EIMAC Electron Tube and Device Group Sales Office.)



Parallel electron "guns" provide electron focusing, low intermodulation distortion, and low grid interception.

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