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BERNARDS RADIO SERIES

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HAM NOTES

FOR THE HOME CONSTRUCTOR

CONTENTS

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A COMPREHENSIVE CRYSTAL CALIBRATOR

By R. W. ADAMS

THE conditions governing the issue of the amateur transmitting licence to-day are far more rigid than was the case before the last war and this is especially true in the matter of the station operator's ability accurately to check his operating frequency. The increasing popularity of the variable frequency oscillator coupled with ever narrowing frequency bands and the increasing number of stations using them has made some form of frequency standard an absolute necessity in the amateur station instead of the luxury it was so often regarded in past years.

In the following paragraphs will be described an instrument which has been developed specifically for such work, being capable of a very high degree of accuracy whilst, at the same time, its construction does not involve the major problems associated with a frequency meter. Since it is intended that it shall be used during actual operation of the station, some care has been taken to make its employment as simple as possible after the initial setting-up process has been completed. This simplification in no way detracts from its use for more involved calibrations so that it can be regarded as the frequency standard for the entire station.

The instrument consists of two separate crystal oscillators, a harmonic amplifier, modulator, multivibrator; a stabilized power supply is also built on to the same chassis. The first oscillator is a relatively simple Pierce circuit into which crystals having fundamental frequencies of 7 Mc, 1 Mc or 500 Kc can be switched at will with the additional advantage that, if required, the 7 Mc crystal may be removed to allow any of the transmitter crystals to be inserted for checking. The second oscillator is somewhat more elaborate and is devoted, solely, to a 100 Kc bar on which the final accuracy of the instrument depends and provision has been made for its frequency to be varied by a few cycles so that it may be referred to a known standard such as the B.B.C. at Droitwich on 200 Kc or the NPL standard frequency transmission on 2 Mc. The 100 Kc oscillator is also made to control a multi-vibrator running at 10 Kc and in this manner a series of known marker signals is obtained which, with their higher order harmonics, provide accurate reference points throughout a wide frequency spectrum. The harmonic amplifier enables the marker signals to be used up to 30 Mc and higher and, when the modulator is switched in, each marker signal is easily identified by a superimposed 400 cycle tone. The accuracy of the 10 Kc multi-vibrator is of the same order as that of the 100 Kc bar and further subdivision of the 10 Kc signal intervals is unnecessary and might even be confusing at higher frequencies, it being found adequate to use simple interpolation in conjunction with the station receiver for the determination of spot frequencies. All the valves, with the exception of the rectifier and voltage control tubes, are of the same type, namely, EF-50, some of which are connected as triodes. Their use for all purposes simplifies the replacement problem by avoiding a multiplicity of valve types.

If reference is made to the circuit diagram, it will be seen that the 100 Kc. oscillator (V_1) is a conventional arrangement which balances out the crystal capacity so that the trimmer condenser C_3 can be used to give a variation of a few cycles in the crystal frequency. Coil L_2 is a two section RF choke with an inductance of 17.9 mH., C_3 being mounted directly on the chassis with its spindle grounded and arranged for screwdriver adjustment. A low value of HT is used for this stage and, as a rule, no difficulty will be found in getting the bar to oscillate. If difficulty is found in this connection the resistors R_3 and R_4 may be lowered in value slightly, but care must be taken to ensure that the output from the stage does not tend to overload the following amplifier; C_5 being kept small, consistent with good output from V_4. The 10 Kc. multi-vibrator (V5 and V_6) will next be considered, since it is most intimately connected with the 100 Kc. oscillator. It will be seen that the EF-50's are connected as triodes and the circuit values have been found to give good locking at 10 Kcs. with R_5 at mid-travel. This variable resistance will usually allow of operation at 9, 10, 11 and, occasionally, 12 Kc. but once set, has been found to remain locked on frequency. If a different circuit layout is adopted it may be found necessary to alter, slightly, the values of R_6 and R_8 to compensate for varying circuit capacities etc.; but best operation will be found to occur when the values of R_6 plus $\frac{1}{2}R_5$ are equal to R_8. The locking signal is obtained via C_5 and C_9 which, in series, comprise a small, but sufficient capacity for the purpose and, in fact, can often be omitted altogether without losing locking, but it will be seen that they perform another function besides this, acting as coupling condensers to the harmonic amplifier (V_4). V_2 is the oscillator for the remaining three crystals which are switched into circuit as required by one section of switch S_4. The circuit is a normal one except for the condensers shunted across the RF choke in the anode circuit and which have been found a help in starting the two lower frequency crystals. Some constructors may prefer to simplify this design somewhat by the omission of the 500 Kc. and 7 Mc. crystals, and this may be accomplished by very small modifications to the switching. In practice, it has been found that the 500 Kc. bar is more of a luxury when operation is confined to the amateur bands, but it is useful when the range of application is wider. The use to which the 7 Mc. crystal can be put, however, will be realised especially when the receiver to be calibrated only covers the amateur bands and the band edge has to be set before further calibration is carried out.

Choice of output frequency is obtained by means of the switch S_4 which is a rotary six-bank wafer type and is marked at each step to show the frequency interval between the output signals (i.e. 10 Kc., 100 Kc., 500 Kc., 1Mc., 7 Mc.). Its action is to select the appropriate crystal in the case of the Pierce circuit, put HT to the oscillator in use and also to the multi-vibrator when required so that there is no ambiguity and no operating time need be wasted in setting up. In the 7 Mc. position, the HT to the oscillator is reduced by the inclusion of R_{11} in the HT feed as the output it too great when the full value is used and the harmonic amplifier would be over-driven.

The harmonic amplifier has signals fed to its grid via the small variable condensers C_5, C_9 and C_{10}, these being adjusted so that the harmonic output from the amplifier is at maximum. In the anode circuit, as will be seen from the diagram, one of a number of coils may be selected at will to cover any part of the spectrum from 100 Kc. to 60 Mc. or higher; the switch in question being S_2. Each coil has a link coupling coil interwound with it so that it can be matched into a co-axial line of any convenient length, but on the lowest frequency range this was not found practicable so that a straightforward capacity output is used in conjunction with the RF choke shown. The tuning condenser C_{19} is left in circuit continuously, even in the first position across the choke.

The last stage to be described is the modulator which is connected as a triode in a Meissner circuit. The transformer is an ordinary audio intervalve component such as most amateurs will possess. The modulator output is fed to the anode of the amplifier, which is modulated by the 400 cycle tone produced by tuning the grid winding of the transformer with condenser C_{24}. The value of this condenser may be varied to produce a note of the required frequency. The negative feedback control R_{17} is mounted on the chassis close to V_3, and when the instrument is set up R_{17} should be adjusted to give a clean note free of harmonics, once set it should require no further adjustment. The modulator is controlled from the panel by its own switch, S_3, so that it can be brought into use at will when it is required to identify any one marker point.

The power supply for the instrument is conventional with the addition of a pair of VR 150/30 stabiliser tubes which hold the HT line voltage to a figure of 300 volts, thus ensuring that the final measurements are not made inaccurate either by mains voltage fluctuations or HT variation when the modulator is brought into use. Indicator lamps associated with the mains on/off and HT switches are provided but for clarity are not shown on the circuit diagram. The mains voltage selector panel is located on the rear apron of the chassis.

A few words, in conclusion, on the correct use of the crystal calibrator will, no doubt, be of some interest to those who have not had the experience of using one and, although the remarks which follow are intended to refer specifically to the calibrator described, they can, from the point of view of actual operation, be applied equally well to a number of instruments available to-day.

The crystals, other than the 100 Kc. bar, are used only as guides to the final frequency and, therefore, it is important to ensure that the accuracy of this bar is as high as possible. We are fortunate in this country, in having an excellent frequency standard of convenient value in the B.B.C's. Droitwich long-wave station on 200 Kc. whose accuracy is within very fine limits. If, therefore, the calibrator be fed into a receiver tuned to this station it is possible to detect, either by ear or by means of a tuning indicator, the beat note between Droitwich and the second harmonic of the 100 Kc. oscillator in the calibrator. If now condenser C_3 be adjusted it should be possible to zero beat the two signals or, at worst, produce a frequency difference of a few beats per second and, this having been accomplished, it should not need re-checking unless the instrument has been in transit or had a change of valve.

The check receiver is next switched to the medium wave-band and two adjacent harmonics of the 100 Kc. oscillator identified (the modulator should be used to ensure that the signals chosen are not confused with carriers from broadcast stations). Next, the 10 Kc. position of S_4 is chosen when the intervening space between the two chosen signals should be divided into a number of equal spaces by similar signals and these should be counted carefully to find out into how many divisions the multi-vibrator is separating the 100 Kc. range. For correct operation there should be nine signals between the two original ones, thus making ten equal divisions of 10 Kc. each. In practice, it will most probably be found that either 8, 10, 11 or 12 signals are counted and, therefore, it will be necessary to adjust R_5 until the correct sub-division is obtained. This done, the instrument is ready for use and the following procedure is suggested as being the quickest method of finding the frequency of an unknown signal. If the receiver, in conjunction with which the calibrator is to be used, has little or no calibration, it will be necessary to determine one or two fixed points of reference in its spectrum and, for this purpose, the 7 Mc. crystal is provided as it also acts as a very good band-edge marker for some of the main amateur bands. It should be possible, with its aid, to locate 7, 14, 21, 28 Mc. on the receiver dial and care should be taken to see that the real and not the image signal is logged; any receiver having an RF stage should discriminate between these two unless the injected signal is very strong. This done, the intervening megacycle points can be found by switching to the 1 Mc. crystal. Similarly, further sub-divisions are made so that, in the end, the unknown frequency is 'bracketed' by two points 10 Kc. apart whose frequency is accurately known. For many purposes this will be sufficient, but if an exact figure is needed it is found by simple interpolation which is best illustrated by a numerical example:—

It is required to find the exact frequency of a point on the receiver dial whose frequency, for example is 14,395 Kcs. The adjacent points which have been found are 14,390 Kc. = 436 deg., and 14,400 Kc = 450 degs. We know that 14 degs. of dial (450—436) = 10 Kc. (14,400—14,390), therefore:—

1 Kc. = 1.4 deg. (dial).

Therefore, 14,395 Kc. = 436 + (5 × 1.4) deg:
= 436 + 7 = 443 degs. dial

The only assumption in the above is that the receiver dial is linear over the small range of 10 Kc. between the last last marker points and this may usually be assumed as the range is comparatively small.

Finally, if care be taken with the construction and setting-up procedure, the calibrator will be found to give consistent service and gives the station operator the confidence of knowing that his VFO and receiver are subject to constant check so that he need have no fear of off frequency working when operating near the edges of the allotted bands.

COMPONENTS

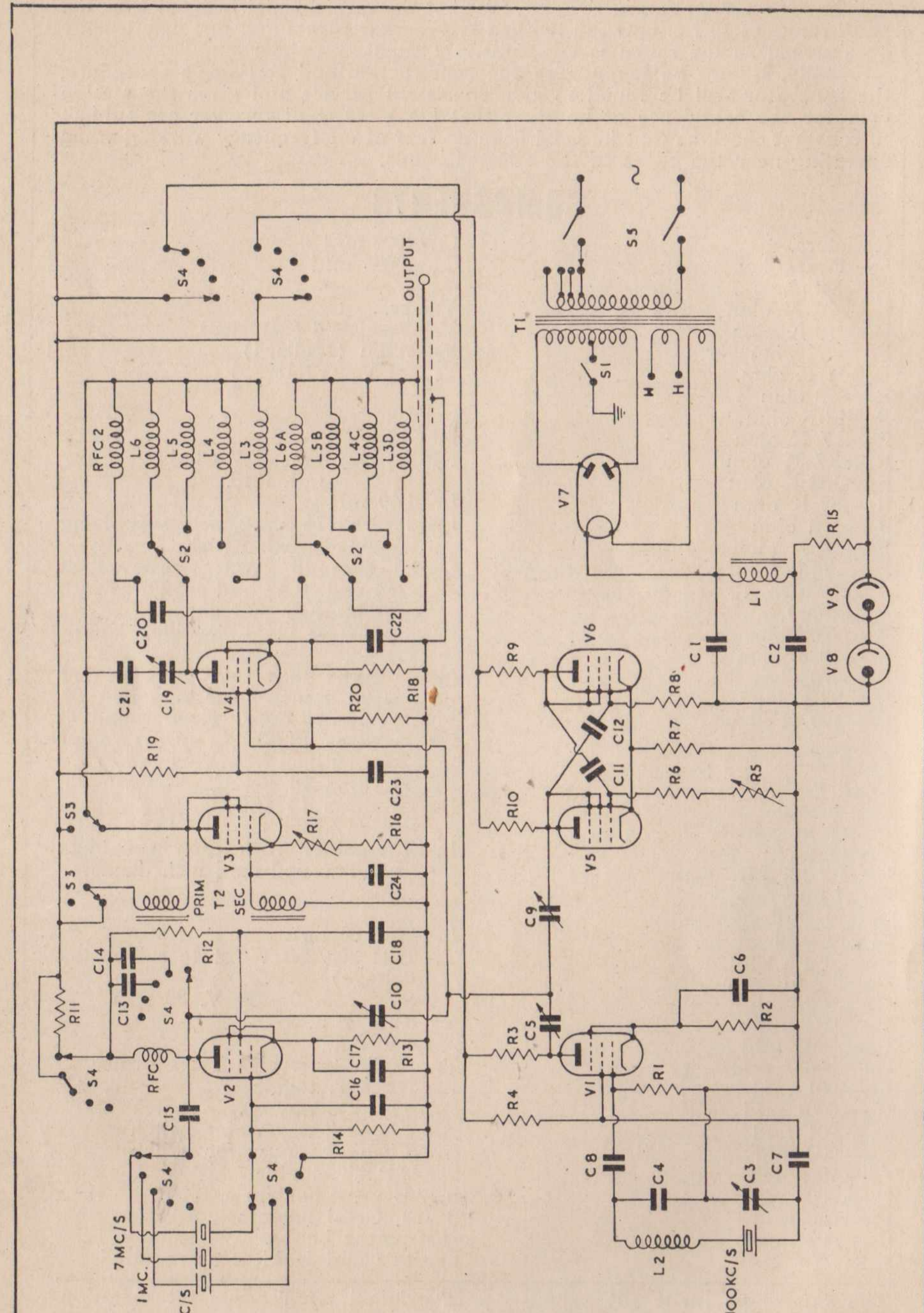
Resistors.
R_1—1 megohm
R_2—390 ohms
R_3—470 K ohm
R_4—470 K ohm
R_5—5 K ohm var.
R_6—11 K ohm
R_7—490 ohm
R_8—12 K ohm
R_9—2.7 K ohm
R_{10}—2.7 K ohm
R_{11}—160 K ohm
R_{12}—82 K ohm
R_{13}—390 ohm
R_{14}—39 K ohm
R_{15}—Adjust to give 15 m/a through through V_8 and V_9 (approx 1,000 ohms).
R_{16}—220 ohms
R_{17}—10 K ohm var.
R_{18}—470 ohm
R_{19}—82 K ohm
R_{20}—100 K ohm

Condensers.
C_1—8 mfd
C_2—16 mfd
C_3—20 pf. var.
C_4—15 pf.
C_5—2-9 pf. var.
C_6—.1 mfd
C_7—.01 mfd
C_8—.01 mfd
C_9—2-9 pf. var.
C_{10}—2-9 pf. var.
C_{11}—.002 mfd
C_{12}—.002 mfd
C_{13}—.0002 mfd
C_{14}—.00047 mfd
C_{15}—.001 mfd
C_{16}—.0001 mfd
C_{17}—.001 mfd
C_{18}—.002 mfd
C_{19}—.0005 mfd. var.
C_{20}—.0001 mfd
C_{21}—.002 mfd
C_{22}—.002 mfd
C_{23}—.002 mfd
C_{24}—.0005 mfd

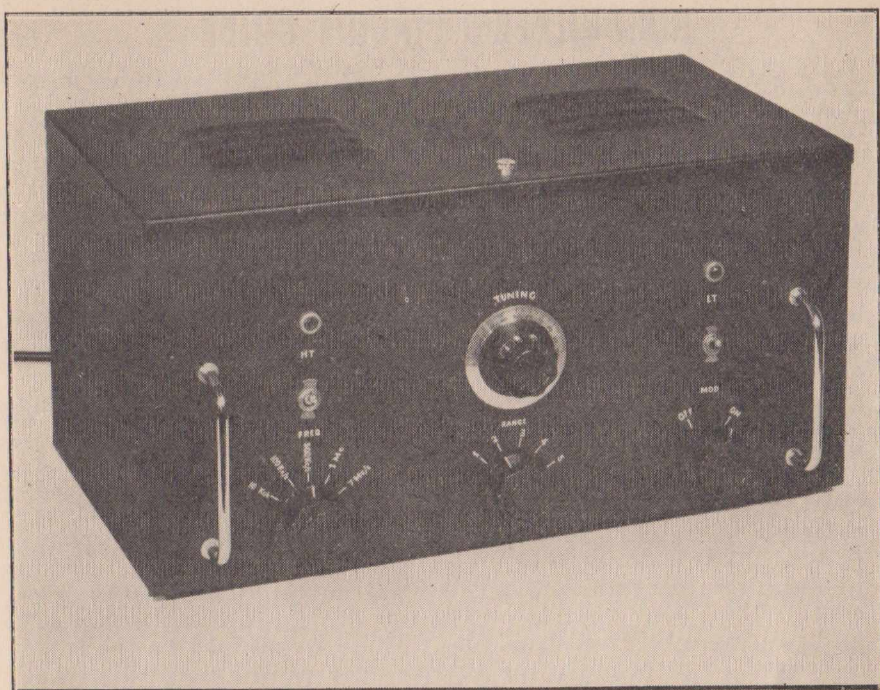
Valves.
V_1—V_6—EF50 (Mullard)
V_7—AZ31 (Mullard)
V_8 and V_9—VR150/30 (U.S.A.)

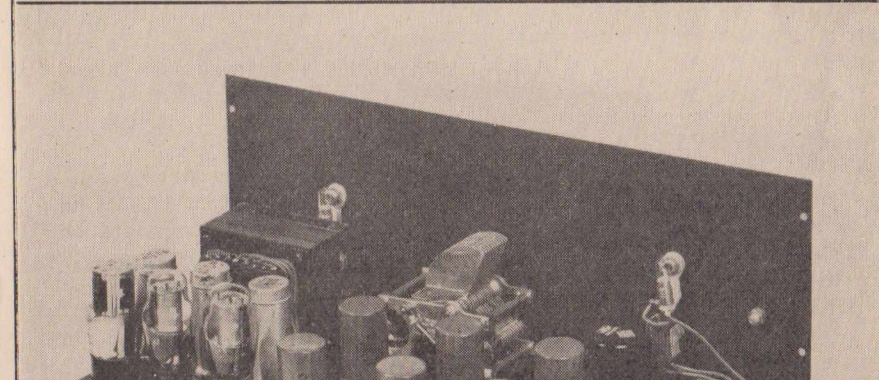
Coils.
RFC1
RFC2 Edystone SW Chokes Cat. 1010.
L_2—17.9 mH
L_3—4 turns 16 s.w.g. self supporting winding length 1 inch
L_3d—1 turn 18 D.C.C. Inserted at cold end of L_3 and cemented into position with coil dope.
L_4—8 turns 18 D.C.C. winding length 1 inch.
L_4c—3 turns 18 D.C.C. close wound spaced ¼ inch from cold end L_4.
L_5—30 turns 18 D.C.C. close wound
L_5b—5 turns 18 D.C.C. close wound spaced ¼ inch from cold end of L_5.
L_6—50 turns 18 D.C.C. close wound.
L_6a—8 turns 18 D.C.C. close wound spaced ¼ inch from cold end of L_6.
L_4-L_6 together with their couplings are all wound on ¾ inch diameter formers.

L_1—20H 80 m/a
T_1—PRI 200/250 V (or to suit mains voltage)
SEC 350—0—350 V. 80 m/a
6.3 v 4 a.
4 v 2 a.
T_2—Audio Intervalve Transformer
S_1—D.P.S.T. toggle
S_2—2 bank 5 way wafer switch
S_3—2 bank 2 way wafer switch
S_4—6 bank 5 way wafer switch
S_5—D.P.S.T. toggle
6 B9G valve holders
3 Int. Octal holders
Instrument knobs.
Crystals and Holders as required.



OUTPUT
S4
S4
S3
T1
S1
H
H
RFC2
L6
L5
L4
L3
L6A
L5B
L4C
L3D
S2
S2
V7
R15
L1
V9
V8
C1
C2
C22
C20
C21
C19
V4
R9
V6
R8
R20
R18
C12
R7
R19
C23
R16
R17
V3
R10
C11
R6
R5
V5
S3
S3
PRIM
T2
SEC
C24
C9
C18
R12
C14
C13
S4
R11
C10
C6
R2
R3
C5
C17
C16
R13
RFC
V2
R1
V1
S4
C15
R4
R14
S4
S4
C8
C4
C3
C7
L2
7MC/S
1MC.
500KC/S
100KC/S


TUNING
HT
LT
FREQ
MOD
OFF
ON
RANGE



RIG-BUILDER'S CIRCUIT GUIDE

RECOGNISING the fact that most R-F and audio circuits change very little from tube to tube, this issue presents six standard circuits. With each circuit are listed the types of tubes which will operate in that circuit, together with the circuit constants which must vary from tube to tube. These six standard circuits are therefore the equivalent of eighty-nine separate circuits.

The single tube circuits (circuits A and B) may be employed as either buffer or final circuits. An untuned grid circuit is shown in order to keep the diagram as simple as possible. Circuits C and D are push-pull circuits and would normally be used as circuits for final amplifiers, although low power tubes in these circuits will allow their use as buffer amplifiers. Circuit E is a class B audio modulator circuit and circuit F is a class AB_2 modulator circuit.

The tube operating conditions given in the tables are, in most cases, the conditions for maximum input. It is important that these limits are not exceeded. The bias voltage given in circuits A, B, C and D is designed to protect the tubes in case of excitation failure, or in case the crystal or VFO circuit is keyed. In the case of these four circuits bias is obtained by a combination of grid resistance bias and fixed bias. These values may be changed if desired. For example the grid resistor can be omitted if the fixed bias is increased. This increase in fixed bias should be equal to the amount of bias that was obtained from the grid resistor due to the grid current (Ig). Conversely the fixed bias can be removed and the grid resistor increased to give the proper bias. This is not recommended unless the stage is protected by an overload relay in the plate circuit.

Values for grid and plate coils and condensers are not specified. Manufactured assemblies may be used, or homemade coils employed. The table gives the airgap necessary for the plate condenser. In the case of split-stator condensers, the airgap given is still valid for each section. This value of spacing allows a 100 per cent factor of safety.

Neutralizing condensers (NC) should have an airgap 50 per cent greater than that of the plate condenser. Maximum usable capacity of the neutralizing condenser should be somewhat greater than the grid to plate capacitance of the tube it is used with.

The wattage of the various resistors is not given. This is easily computed by I^2R, where I is the current through the resistor (grid current or screen current). Use a wattage rating which is approximately double the computed value, as a safety factor.

CIRCUIT A

The filament bypass condensers may be of the 600 volt paper type. The 0.001 mf plate bypass condenser should have a voltage rating of twice the d-c voltage for c-w operation and three to four times the d-c voltage for phone operation. The RF choke should be of the all-band type and be capable of handling the d-c plate current.

CIRCUIT B

The circuit as shown is for phone operation only. If c-w operation is desired, omit resistor R_2, and use a separate source of voltage on the screen grid as indicated in the table. Circuit B is used for tetrodes, beam power tubes, and pentodes. If the beam-forming plates of the beam tubes are brought out to a pin connection, they should be connected to the centre-tap of the filament transformer. If the tube has a cathode connection, it should be connected to ground. The suppressor grid in pentodes should also be grounded, unless the table indicates that a positive voltage is required. In the latter case a well-regulated source such as a battery should be used.

The filament bypass condensers may be of the 600 volt paper type. The 0.002 mf plate bypass condenser should have a working voltage of twice the d-c voltage for c-w operation and three to four times the d-c voltage for phone operation. The screen bypass condenser (0.005 mf) should be rated at twice the screen voltage for c-w work and three to four times the screen voltage for phone operation.

CIRCUIT C

This circuit is the push-pull version of circuit A. The same comments apply regarding bypass condensers. In addition, the 0.01 mf grid circuit bypass condenser may be a 600 volt paper condenser for most circuits, unless the bias voltage is very high, in which case a 1,250 or 2,500 volt mica is preferable.

CIRCUIT D

Push-pull tetrodes, beam power tubes or pentodes may be used in this circuit. As in the case with circuit B, the diagram shown is for phone operation only. For c-w operation remove R_2 and supply screen voltage from a separate source. All remarks regarding beam-forming plates, cathodes and suppressor grids pertaining to circuit B also apply to circuit D. Similarly, the comments on bypass condensers also apply.

CIRCUIT E

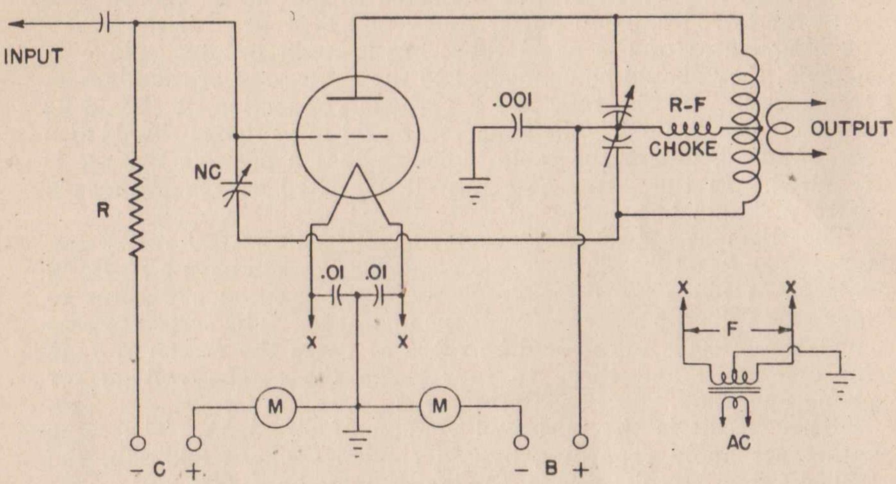
This class B modulator circuit is quite straightforward. The table gives complete operating data, including output impedance, plate-to-plate. Grid bias requirements are small, so that batteries may be used in most cases. Two tubes, the GL-811 and the GL-838, are zero bias tubes. In this case the C— and C+ terminals may be tied together.

CIRCUIT F

Tetrodes, beam tubes or pentodes may be used as class AB_2 modulators in this circuit. Both transmitting tubes and receiving tubes are included in the table. Beam tubes with an external connection for the beam-forming plates should be used with the beam-forming plates tied to the centre tap of the filament transformer. Tubes with cathodes should have the cathode grounded, and pentodes should have their suppressor grid grounded unless the table indicates otherwise.

It is necessary to use a well-regulated source of voltage for the screen-grid supply (+SG). For this reason a separate power supply is recommended. It is possible to use a voltage divider circuit, but the screen current varies so much in operation that the divider must draw a current equal to the screen-grid current. The divider is thus not economical.

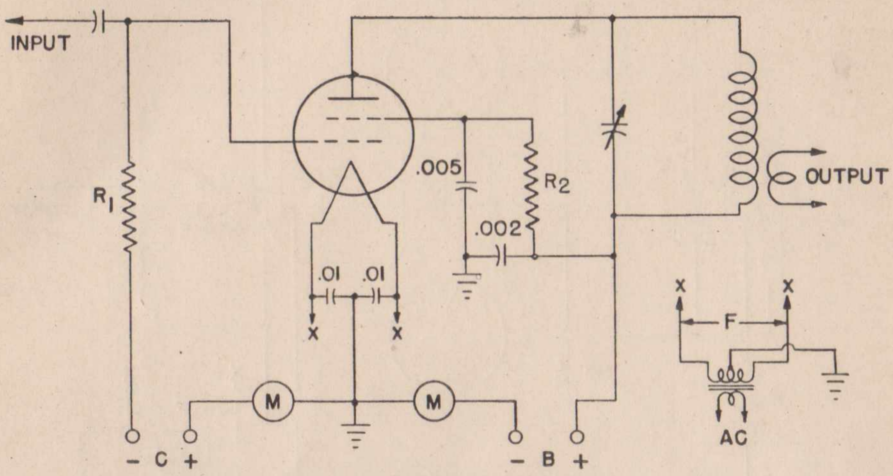
TRIODE
BUFFER OR FINAL



CIRCUIT A

Tube Type	Input Watts		B		C		I_g ma		R ohms	F volts	Airgap (inches)	
	CW	PH	CW	PH	CW	PH	CW	PH			CW	PH
GL-35T	250	168	2000	2000	45	105	45	23	2,000	5.0	.100	.250
GL-100TH	495	366	3000	3000	75	215	51	26	2,500	5.0	.200	.500
GL-203A	188	150	1250	1000	80	45	25	50	1,800	10.0	.070	.100
GL-211	188	150	1250	1000	135	90	18	35	5,000	10.0	.070	.100
GL-592	600	395	2600	2500	90	200	45	45	3,500	10.0	.175	.375
GL-805	300	200	1500	1250	45	70	40	60	1,500	10.0	.078	.144
GL-806	990	585	3300	3000	250	440	40	27	8,750	5.0	.250	.500
GL-810	620	450	2250	1800	45	45	40	50	3,000	10.0	.150	.225
GL-811	225	156	1500	1250	45	25	35	50	2,000	6.3	.078	.144
GL-812	225	156	1500	1250	95	45	25	25	3,200	6.3	.078	.144
GL-838	188	150	1250	1000	45	45	30	60	1,500	10.0	.070	.100
GL-1623	100	75	1000	750	45	75	20	20	2,500	6.3	.070	.084
GL-8000	750	500	2500	2000	135	275	40	37	2,500	10.0	.175	.250
GL-8005	300	238	1500	1250	90	160	32	28	1,250	10.0	.078	.144

TETRODE, PENTODE & BEAM POWER BUFFER OR FINAL

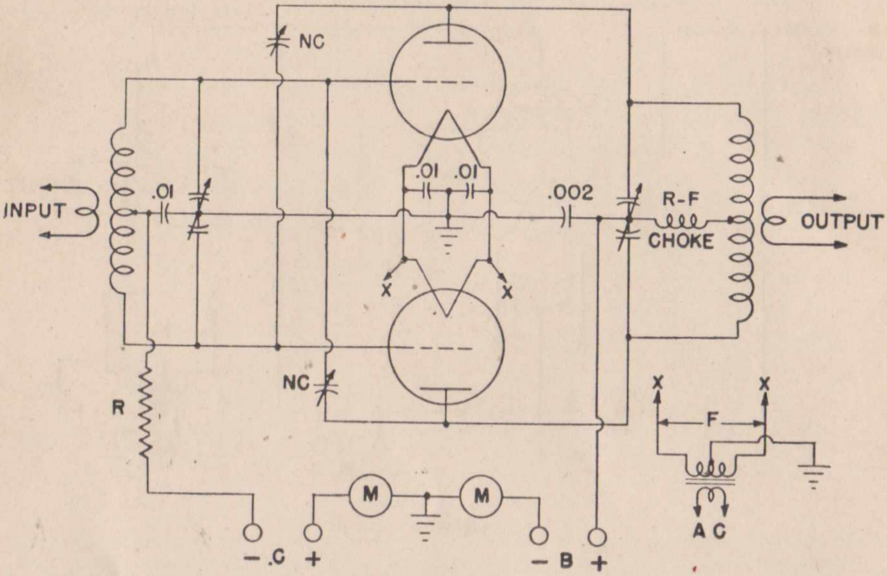


CIRCUIT B

Tube Type	Input watts		B		C		I_g ma		R_1 ohms	R_2 ohms PH*	E_{sg} volts		Airgap (inches)	
	CW	PH	CW	PH	CW	PH	CW	PH			CW	PH	CW	PH
GL-2E24	40	27	600	500	20	15	3	3	10,000	40,000	195	180	.050	.070
GL-2E26	40	27	600	500	15	20	3	3	10,000	35,000	185	180	.050	.070
GL-4D21	500	375	3000	2500	90	150	9	9	7,000	71,500	350	350	.200	.375
GL-802**	33	20	600	500	45	0	2	2	27,000	17,000	250	245	.050	.070
GL-803†	320	240	2000	1600	45	0	12	20	37,500	20,000	500	500	.100	.200
GL-807	75	60	750	600	20	60	4	4	7,000	50,000	250	275	.050	.070
GL-813	360	240	2000	1600	45	70	3	4	15,000	60,000	400	400	.100	.200
GL-814	225	180	1500	1250	45	60	10	10	4,500	43,000	300	300	.078	.144
GL-828‡	270	200	1500	1250	45	85	12	12	4,500	30,000	400	400	.078	.144
GL-837**	30	18	500	400	45	0	4	5	7,500	13,000	200	140	.050	.050
GL-1613	18	12	350	275	0	0	4	4	10,000	7,500	200	200	.030	.030
GL-1614	30	23	375	325	0	0	2	2	20,000	10,000	250	245	.030	.030
GL-1619	30	20	400	325	0	20	5	3	11,000	5,000	300	285	.030	.030
GL-1624	54	38	600	500	45	45	5	3	3,000	25,000	300	275	.050	.070
GL-1625	75	60	750	600	20	60	4	4	7,000	50,000	250	275	.050	.070

*Phone only; see text. **Suppressor grid voltage = +40 volts.
†Suppressor voltage of +40 for CW and +100 for phone.
‡Suppressor voltage = +75 volts.

PUSH-PULL TRIODE
BUFFER OR FINAL

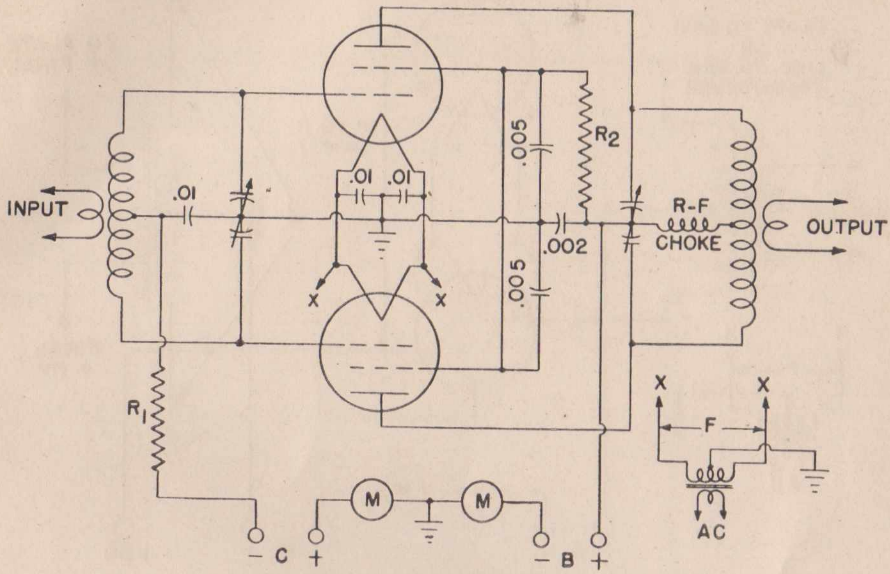


CIRCUIT C

Tube Type	Input watts CW	Input watts PH	B CW	B PH	C CW	C PH	I_g ma CW	I_g ma PH	R ohms	F volts	Airgap (inches) CW	Airgap (inches) PH
GL-35T	500	336	2000	2000	45	105	90	46	1,000	5.0	.100	.250
GL-100TH	990	732	3000	3000	75	215	102	52	1,250	5.0	.200	.500
GL-203A	376	300	1250	1000	80	45	50	100	900	10.0	.070	.100
GL-211	376	300	1250	1000	135	90	36	70	2,500	10.0	.070	.100
GL-592	1000	790	2500	2500	80	200	90	90	1,750	10.0	.175	.375
GL-805	600	400	1500	1250	45	70	80	120	750	10.0	.078	.144
GL-806	1000	1000	2500	2500	250	200	50	80	5,000	5.0	.175	.375
GL-810	1000	900	2000	1800	45	45	80	100	1,500	10.0	.100	.225
GL-811	450	312	1500	1250	45	25	70	100	1,000	6.3	.078	.144
GL-812	450	312	1500	1250	95	45	50	50	1,500	6.3	.078	.144
GL-826	250	150	1000	800	35	65	70	70	500	7.5	.070	.084
GL-838	376	300	1250	1000	45	45	60	120	750	10.0	.070	.100
GL-1623	200	150	1000	750	45	75	40	40	1,250	6.3	.070	.084
GL-8000	1000	1000	2000	2000	135	275	50	75	1,250	10.0	.100	.250
GL-8005	600	476	1500	1250	90	160	64	56	625	10.0	.078	.144

All values are for two tubes.

PUSH-PULL TETRODE, PENTODE & BEAM POWER BUFFER OR FINAL

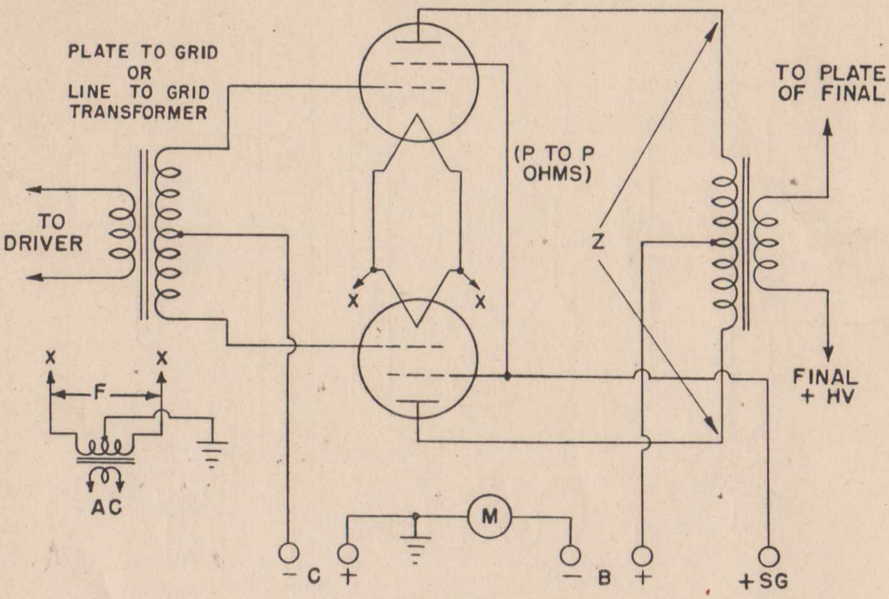


CIRCUIT D

Tube Type	Input watts		B		C		I_g ma		R_1 ohms	R_2 ohms PH*	E_{sg} volts		Airgap (inches)	
	CW	PH	CW	PH	CW	PH	CW	PH			CW	PH	CW	PH
GL-2E24	80	54	600	500	20	15	6	6	5,000	20,000	195	180	.050	.070
GL-2E26	80	54	600	500	15	20	6	6	5,000	17,500	185	180	.050	.070
GL-4D21	1000	750	3000	2500	90	150	18	18	3,500	35,500	350	350	.200	.375
GL-802**	66	40	600	500	45	0	4	4	13,500	8,500	250	245	.050	.070
GL-803†	640	480	2000	1600	45	0	24	40	19,000	10,000	500	500	.100	.200
GL-807	150	120	750	600	20	60	8	8	3,500	25,000	250	275	.050	.070
GL-813	720	480	2000	1600	45	70	6	8	7,500	30,000	400	400	.100	.200
GL-814	450	360	1500	1250	45	60	20	20	2,250	21,500	300	300	.078	.144
GL-815‡	75	60	500	400	20	20	3	3	8,000	15,000	200	175	.050	.050
GL-828 ◉	540	400	1500	1250	45	85	24	24	2,250	15,000	400	400	.078	.144
GL-829B‡	120	90	750	600	20	35	12	12	3,000	13,000	200	200	.050	.070
GL-832A‡	36	21	750	600	45	45	3	3	6,750	25,000	200	200	.050	.070
GL-837**	60	36	500	400	45	0	9	10	3,750	6,500	200	140	.050	.050
GL-1613	36	24	350	275	0	0	8	8	5,000	3,750	200	200	.030	.030
GL-1614	60	46	375	325	0	0	4	4	10,000	5,000	250	245	.030	.030
GL-1619	60	40	400	325	0	20	10	6	5,500	2,500	300	285	.030	.030
GL-1624	108	76	600	500	45	45	10	6	1,500	12,500	300	275	.050	.070
GL-1625	150	120	750	600	20	60	8	8	3,500	25,000	250	275	.050	.070

*Phone only; see text. **Suppressor grid voltage = +40 volts.
†Suppressor voltage of +40 for CW & +100 for phone.
‡Single tube operation.
◉ Suppressor voltage = +75 volts.
All values are for two tubes.

CLASS AB2 MODULATORS

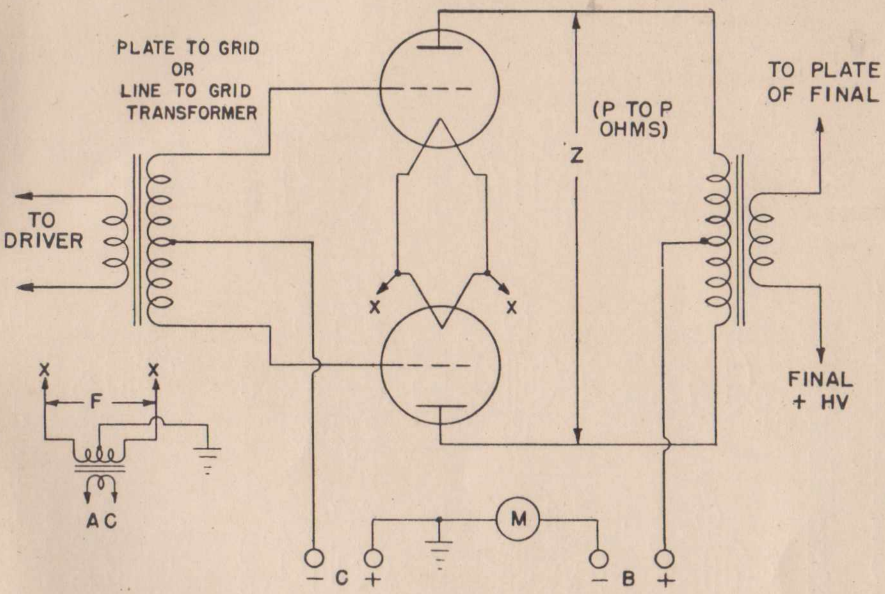


CIRCUIT F

Tube Type	F volts	Audio output watts	Peak grid power watts	B	C	SG	Max. sig. I_p ma	Max. sig. I_{sg} ma	Z ohms
GL-2E26	6.3	54	0.36	500	15	125	150	32	8,000
GL-4D21	5.0	520	2.5	3000	51	350	260	3.5	27,700
GL-807*	6.3	120	0.5	750	32	300	240	10	6,960
GL-813	10.0	515	0.1	2250	90	750	315	58	18,500
GL-815†	6.3	54	0.36	500	15	125	150	32	8,000
GL-828‡	10.0	385	....	2000	120	750	270	60	18,500
GL-1619	2.5	36	0.4	400	16	300	150	11.5	6,000
GL-1624	2.5	72	1.2	600	25	300	180	15	7,500
GL-1625	12.6	120	0.5	750	32	300	240	10	6,960
2A5	2.5	18.5	....	375	26	250	82	19.5	10,000
42	6.3	18.5	....	375	26	250	82	19.5	10,000
6F6	6.3	18.5	....	375	26	250	82	19.5	10,000
6L6	6.3	31	....	360	18	225	142	11	6,000
6V6*	6.3	10	....	250	15	250	79	13	10,000

*Class AB_1 †Single tube operation.
‡Suppressor voltage = +60 volts.
All values are for two tubes.

CLASS B MODULATORS



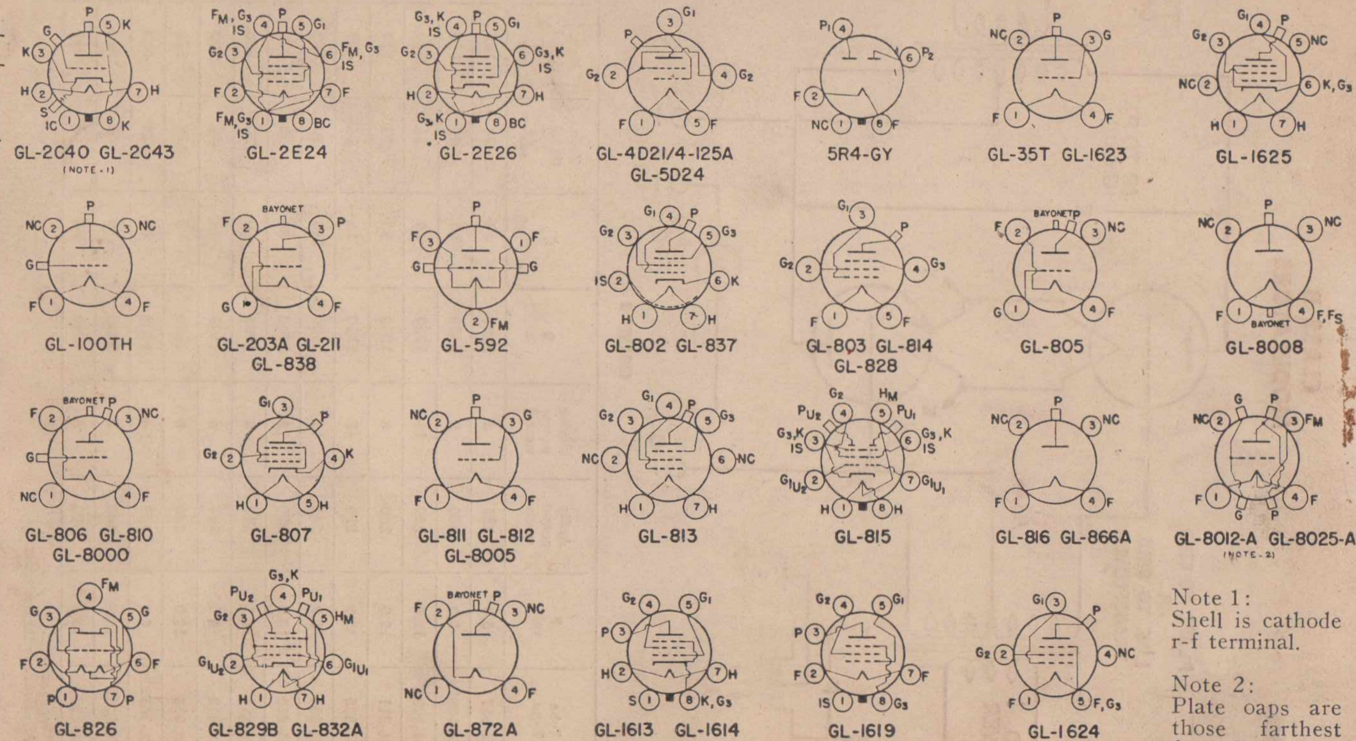
CIRCUIT E

Tube Type	F volts	Audio output watts	Driving power watts*	B	C	Zero signal I_p ma	Max. signal I_p ma	Z ohms
GL-35T	5.0	235	4	2000	40	34	167	27,500
GL-100TH	5.0	650	5	3000	65	40	215	31,000
GL-203A	10.0	260	11	1250	40	26	320	9,000
GL-211	10.0	260	8	1250	95	20	320	9,000
GL-805	10.0	370	7	1500	16	84	400	8,200
GL-806	5.0	535	19	2000	140	80	390	18,000
GL-810	10.0	590	10	2000	50	60	420	11,000
GL-811	6.3	225	4	1500	0	20	200	18,000
GL-812	6.3	225	5	1500	46	42	200	18,000
GL-838	10.0	260	8	1250	0	148	320	9,000
GL-1623	6.3	145	4	1000	40	30	200	12,000
GL-8000	10.0	600	7	2000	120	60	425	10,800
GL-8005	10.0	300	4	1500	70	40	310	10,000

*Approximate.
All values are for two tubes.

SOCKET CONNECTIONS

(Bottom View)



Note 1:
Shell is cathode r-f terminal.

Note 2:
Plate oaps are those farthest from base.

Key: BC—Base Sleeve; F—Filament; Fm—Filament centre-tap; G—Grid; H—Heater; Mm—Heater centre-tap; IC—Internal connection (do not use); IS—Internal shield; K—Cathode; NC—No connection; P—Plate; S—Shell; U—Unit.

Acknowledgments

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