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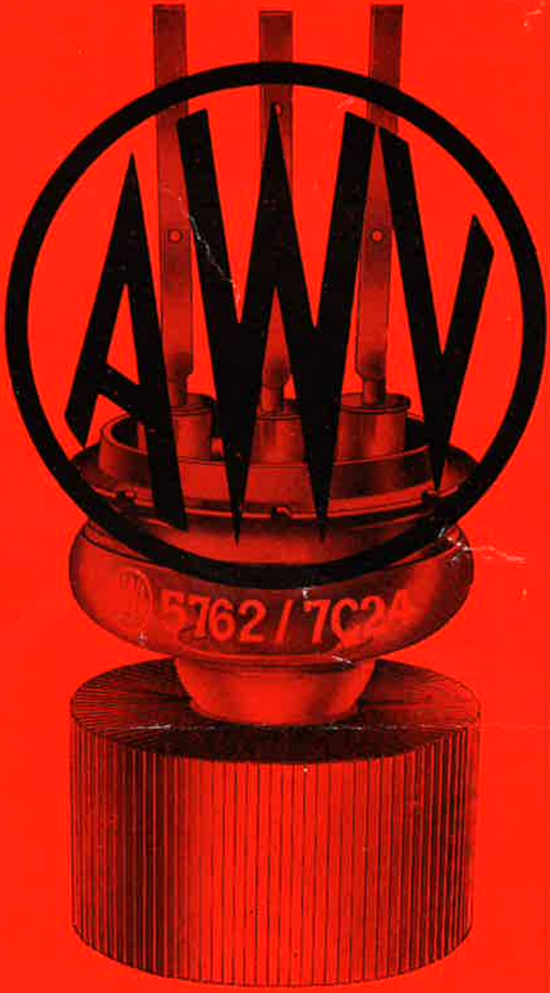

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AMALGAMATED WIRELESS VALVE COMPANY PTY. LTD.

EDITORIAL

CONTENTS

In this issue we print the third in the series, Modern Methods of Testing Amplifiers, dealing with Harmonic Measurement using the Wave Analyser. This is the first time anywhere in the world that a comprehensive and accurate article has appeared on this subject. It is usually assumed that a Wave Analyser can be applied directly to an oscillator or amplifier to measure the harmonic distortion accurately. This is far from the truth for measuring harmonics of 1% or less, as is demonstrated in the article.

Even though most radio engineers do not have the use of a Wave Analyser, this article will be of the greatest interest.

We also print the second instalment of the article on the design of single ended Class C amplifiers, the first instalment of which appeared in the February issue.

Next month we hope to publish a television article originating from our own Applications Laboratory, on the measurement of the power dissipated by the plate of a horizontal-deflection output valve. Shorter articles will deal with the minimum audible change in power output, additional notes on square wave testing and a very useful graphical method for determining the resultant of two resistors in parallel.

Arthur J. Gabb.

Editor .. .. A. J. Gabb, B.Sc.
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MODERN METHODS OF TESTING AMPLIFIERS

(3) HARMONIC MEASUREMENT USING WAVE ANALYSER

By F. LANGFORD-SMITH

The Wave Analyser is undoubtedly one of the most valuable tools for the measurement of non-linear distortion. It may be used to measure each harmonic separately, as a percentage of the fundamental.

Although the conventional Wave Analyser may be used without any special precautions for measuring harmonics of the order of 2% and above, its use at lower levels is complicated by its own internal non-linear distortion which in extreme cases may be greater than that of the amplifier being tested.

To measure accurately the harmonic distortion of an amplifier, it is necessary first to apply to its input terminals a test voltage of the desired frequency which is free from measurable harmonics. But it is not sufficient merely to connect a Wave Analyser to the oscillator terminals and read the harmonics — what will be read under these conditions is the resultant of the components in the oscillator and the Wave Analyser, either in or out of phase.

Removing oscillator harmonics.

The only satisfactory way to eliminate the harmonics at the amplifier input terminals is to connect a suitable filter between the oscillator and the amplifier. One such filter is required for each of the frequencies at which accurate measurements are to be made. The most important for this purpose is 1000* c/s, and this is the only one for which filters are at present in use in the Radiotronics Laboratory. At lower and higher frequencies the amplifier distortion is always higher, and errors caused by a low distortion oscillator are usually only slight. This filter may take either of two forms:

(a) Separate null networks for each of the harmonics having measurable distortion. For a normal RC oscillator operating close to minimum excitation these are limited to second and third harmonics.

(b) A suitable band-pass filter. This has only slight advantages over the use of null networks for use with a Wave Analyser, but it is of great value with a Total Distortion Meter. One is now being built, and will be described in a later issue of Radiotronics.

Measuring oscillator distortion.

As stated above, if a Wave Analyser is connected directly to the output of the oscillator, the readings will be partly due to the Wave Analyser. In the case of the particular General Radio Type 736A used for these measurements, the second harmonic distortion arising in the Wave Analyser was measured as 0.20% and third harmonic 0.055% when the pure applied fundamental was set to 300 millivolts (see Appendix 2). The method used for the measurement of oscillator distortion is shown as a block diagram in Fig. 1. The oscillator feeds through the harmonic filter which has a cathode follower output. A harmonic filter is one which passes the fundamental frequency but severely attenuates harmonics. The amplifier is a special low distortion laboratory amplifier with less than 0.008% second harmonic and less than 0.001% third harmonic at 1 volt output — well above the level used for the Wave Analyser. Details of this amplifier, and the method of measurement of the distortion, will be given in a future issue of Radiotronics.

The cathode follower output stage is used to drive a 200 c/s High Pass Filter (see Appendix 4) which is cut out of circuit when measuring the fundamental, connected to the Wave Analyser. The purpose of the High Pass Filter is to permit each harmonic to be measured while the fundamental is heavily attenuated. If this High Pass Filter is not used, the non-linearity in the Wave Analyser contributes to the second and possibly third harmonic distortion. For a full description of the procedure used see Appendix 1.

Using this method, the oscillator distortion was found to be 0.05% second harmonic, while the third harmonic was 0.02%. When the same test was repeated without use of the High Pass Filter, with the Wave Analyser set to 300 mV, the distortion indicated was much higher — 0.25% second and 0.075% third harmonics (see Appendix 2).

Measuring amplifier distortion.

The procedure to be adopted for the measurement of amplifier distortion is the same as for measuring oscillator distortion, except that in this case the amplifier is the one under test (Fig. 1). The procedure is set out in Appendix 1.

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* Some laboratories use 400 c/s.

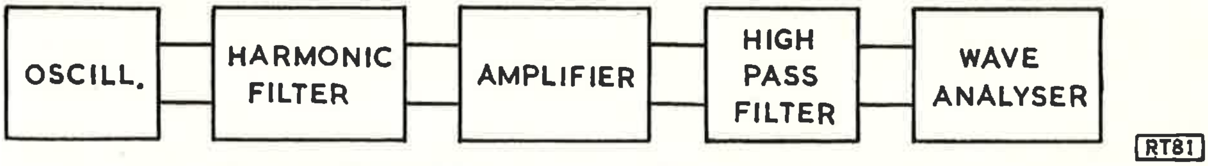


Fig. 1. Method used for measuring oscillator distortion (RT81).

Appendix 1: Procedure used.

If a constant frequency true 1000 c/s source is available, the procedure is simplified, because the Wave Analyser can readily be set to its second or third harmonic and the oscillator set to either the fundamental or one of the harmonics as required.

If such a source of 1000 c/s is not available the following procedure (1.11 to 1.14) has been used in the Radiotronics Laboratory. This method ensures that, even though the fundamental frequency used for these tests may differ somewhat from 1000 c/s, at least there is no doubt that the null networks are correctly adjusted in relation to the oscillator frequency.

same loss for the fundamental as for the harmonics. See Appendix 4 below.

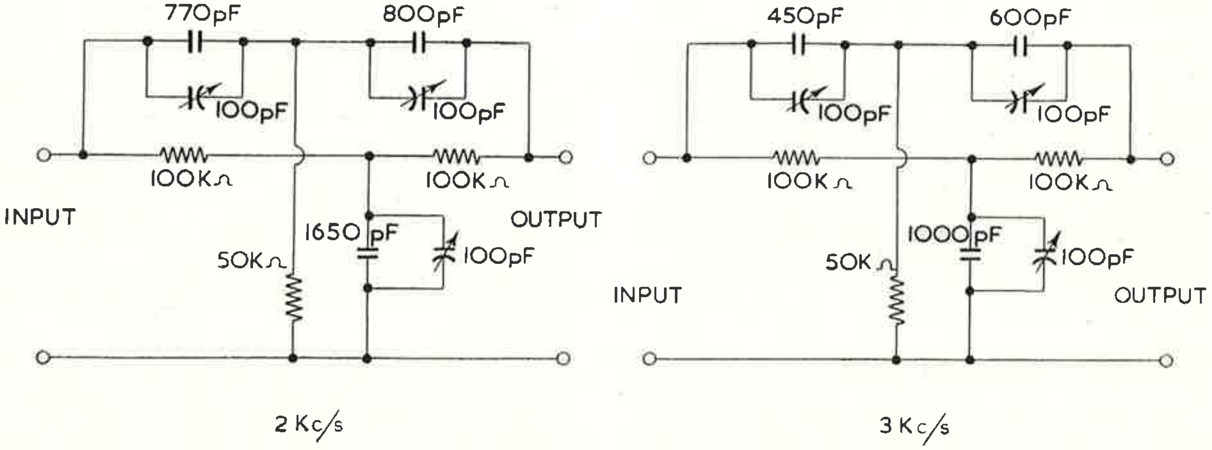
1.16. Adjust the amplifier output voltage to the desired value.

1.17. Measure the amplifier second harmonic with the W.A. Repeat with a similar method for third harmonic (3000 c/s).

In our case the oscillator has no harmonics higher than the third, and therefore it is possible to short-circuit the null network for fourth and higher harmonics.

2. Results of measurements made on the low distortion laboratory amplifier and G.R. 736A Wave Analyser.

Tests were made under all possible combinations of conditions (harmonic filter in and out, high



PARALLEL T NETWORKS

Fig. 2. Circuit diagrams of 2000 and 3000 c/s Parallel-T Null Networks (RT76).

1.1. Procedure for setting up using 2000 and 3000 c/s null networks.

1.11. Set the W.A. to 2000 c/s.

1.12. Adjust the oscillator frequency identical to that of the W.A.

1.13. Insert the 2000 c/s null network between the oscillator and the W.A. and adjust the three controls of the null network very carefully, to give a proper minimum.

1.14. Tune the oscillator to 1000 c/s by picking up its second harmonic (2000 c/s) on the W.A. which has not been altered in frequency (with the null network shorted*).

NOTE.

If a fairly broad band-pass filter is used in place of the null networks, no special care is necessary in setting up to the exact frequency.

work.

1.15. Remove the short across the null network, connect the amplifier to be tested and insert the high pass filter between the amplifier and the W.A. The Harmonic Output terminal (Fig. 4) is used when measuring the harmonics; these are attenuated by the filter. The fixed attenuator R_1, R_2 provides the

pass filter in and out) in an endeavour to derive the individual distortions of the oscillator amplifier and wave analyser. The results are tabulated in Table 1.

It will be seen that the second harmonic of the amplifier alone is 0.13% at 16 volts output, with 300 mV and both networks (Test B1). Since the distortion is roughly proportional to the output voltage, we may infer that the second harmonic at 1 volt output will be approximately 0.008%. The 300 mV condition was selected in preference to the 100 mV one, because is gives a more accurate reading when the High Pass Filter is used, although both should agree with the margin of error (about ±25% at these very low levels). The amplifier third harmonic is shown as "nil" even at 16 volts output (B2). This means that the harmonic is less than 0.015%, the lowest readable value on the 300 mV setting. Hence at 1 volt output the third harmonic will be less than 0.001%.

* In practice it has been found possible to carry out this procedure without having to shortcircuit the null network.

The oscillator distortion is derived from the test with the null network omitted, but with the H.P. filter in circuit. It will be seen that the second harmonic drops down to 0.04% set at 300 mV (B3) or 0.05% set at 100 mV (A3), at low output voltages. The second harmonic was taken as 0.05% as the higher of the two readings, but this includes a slight amount of amplifier distortion, say 0.008% at 1 volt, which may add to or subtract from the value of 0.05%, to give an oscillator second harmonic of 0.05 ± 0.008%. Similarly, the oscillator third harmonic is 0.02 ± 0.001% (B4).

The Wave Analyser distortion is 0.20% second harmonic (B5), and 0.055% third harmonic (B6) when the W.A. is set at 300 mV; this is derived from the tests with the null network in circuit and the high-pass filter omitted, at low output levels. With the W.A. set to 100 mV, the second harmonic is 0.12% (A5) while the third harmonic is "nil" (A6), i.e., less than 0.03%.

The combined oscillator and wave analyser distortion is given in A7, A8, B7 and B8 at low levels. At the 300 mV setting this gives 0.30% second harmonic (B7) with an accuracy of about ±25%. However, this should be equal to the sum of oscillator (0.05%) and wave analyser distortion (0.20%), that is 0.25%, which is the value shown in Table 2.

Similarly the combined oscillator and wave analyser third harmonic on the 300 mV setting is 0.11% (B8) with an accuracy of about ±25%. This should be equal to the sum of oscillator (0.02%) and wave analyser third harmonic (0.055%), that is 0.075%, which is the value shown in Table 2. The discrepancy between these two values (0.11% and 0.75%) is greater than the assumed tolerances, but it was not possible to repeat the test before publication. This is the only case where such an unexplained discrepancy occurs.

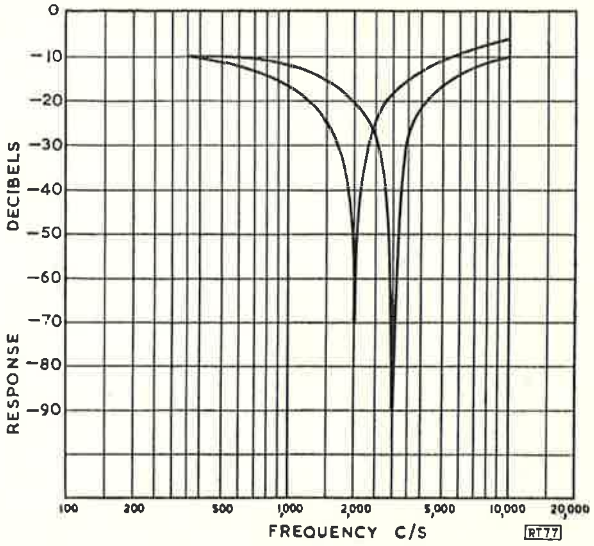


Fig. 3. Attenuation characteristics of the Null Networks shown in Fig. 2 (RT77).

The combined oscillator and wave analyser second harmonic on the 100 mV setting is 0.12% (A7), whereas this should be equal to the sum of oscillator (0.05%) and wave analyser (0.12%) namely 0.17%. This checks well within the tolerances. The third harmonic similarly is 0.06% (A8), whereas this should be equal to the sum of the oscillator (0.02%) and wave analyser (0.03%), namely 0.05%; the agreement is quite good.

3. Details of 2000 and 3000 c/s null networks.

The circuit diagrams are shown in Fig. 2. Small 100 $\mu\mu$F trimmer capacitors were used for all adjustments, which were made with an ordinary trimmer tool (screwdriver). The whole assembly was completely screened.

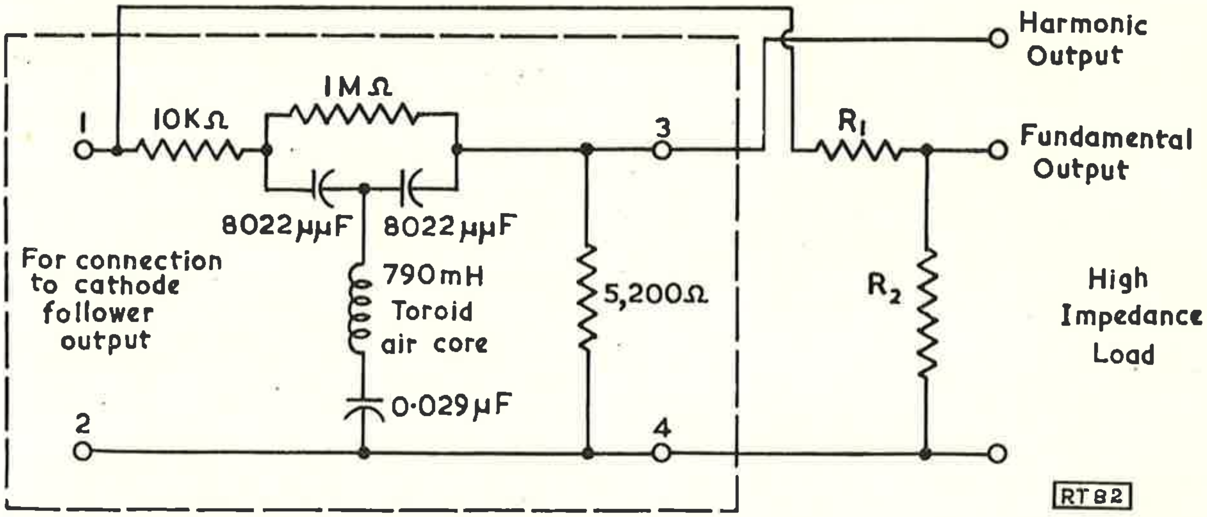


Fig. 4. Circuit diagram of High-Pass Filter (RT82). The portion shown inside the dashed lines is supplied as a unit mounted in a metal box by Telephone Manufacturing Co. (Australasia) Pty. Ltd.,

TABLE 1.

Set W.A.	Null Network	H.P. Filter	Harm.	Harmonics %						Test
				16	8	4	2	1	0.5V	
100 mV	yes	yes	H_2	0.15	0.06	0.045	nil	nil	nil	A1
	yes	yes	H_3	nil	nil	nil	nil	nil	nil	A2
	no	yes	H_2	.11	.11	.05	.05	0.5	.05	A3
	no	yes	H_3	.03	.03	nil	nil	nil	nil	A4
	yes	no	H_2	.48	.24	.18	.15	.12	.12	A5
	yes	no	H_3	nil	nil	nil	nil	nil	nil	A6
	no	no	H_2	.27	.24	.20	.18	.135	.12	A7
	no	no	H_3	.09	.075	.06	.06	.06	.06	A8
300 mV	yes	yes	H_2	.13	.07	.035	.02	nil	nil	B1
	yes	yes	H_3	nil	nil	nil	nil	nil	nil	B2
	no	yes	H_2	.08	.075	.06	.05	.04	.04	B3
	no	yes	H_3	.035	.03	.035	.025	.02	.02	B4
	yes	no	H_2	.55	.35	.25	.20	.20	.20	B5
	yes	no	H_3	.06	.055	.055	.055	.055	.055	B6
	no	no	H_2	.40	.36	.33	.30	.30	.30	B7
	no	no	H_3	.15	.135	.12	.11	.11	.11	B8

* nil = no indication given on Wave Analyser.

TABLE 2.

Summary of individual second and third harmonics as determined from the basic measurements in Table 1. Accuracy of individual values about ±25%.

	Source
Amplifier distortion at 16 volts output	
H_2 . . . . 0.13%	B1
H_3 . . . . <0.015%	B2
Amplifier distortion at 1 volt output	
H_2 . . . . 0.008%	B1
H_3 . . . . <0.001%	B2
Oscillator distortion	
H_2 . . . . 0.05%	A3
H_3 . . . . 0.02%	B4
Wave Analyser Distortion (300 mV setting)	
H_2 . . . . 0.20%	B5
H_3 . . . . 0.055%	B6
Wave Analyser distortion (100 mV setting)	
H_2 . . . . 0.12%	A5
H_3 . . . . <0.03%	A6
Oscillator and Wave Analyser (300 mV) distortion	
H_2 . . . . 0.25%	text
H_3 . . . . 0.075%	text
Oscillator and Wave Analyser (100 mV) distortion	
H_2 . . . . 0.17%	text
H_3 . . . . 0.05%	text

The attenuation characteristics, when correctly adjusted, are as in Fig. 3. These are drawn with the oscillator set to the harmonic frequency. When correctly adjusted there can be no doubt that the relevant harmonic is attenuated to the degree shown in Fig. 3, even though a Wave Analyser or Total Distortion Meter, used without any of the precautions described in this article, does indicate harmonics.

The only practical problem found in the use of these networks is the slow drift in frequency either of the oscillator or the null network, or both, requiring resetting before commencing each series of tests.

As soon as the new 1000 c/s band-pass filter is available, it is proposed to cease using these two null networks.

4. Details of High Pass Filter.

The circuit diagram is shown in Fig. 4. The filter includes a 1 megohm resistor shunt to give very high attenuation at 1000 c/s.

The 790 millhenry inductor is an air-core toroid. The capacitors are silvered mica. The 0.029 μF capacitor was originally 0.033, trimmed down to produce infinite attenuation at 1000 c/s. The resistors are carbon ±10%.

Insertion loss at 2 Kc/s and above 9.2 db.
Loss at 1000 c/s greater than 50 db.
Loss at 930 and 1050 c/s greater than 40 db.

The fixed attenuator R_1, R_2 provides the same loss of the fundamental as the filter provides for the harmonics. In our case R_1 = 130,000 ohms and R_2 = 68,000 ohms.

Additional test results are given on P.62.

SINGLE-ENDED CLASS C AMPLIFIER DESIGN

(*Continued from February Issue*) — on P.16.

Having selected an RCA-813 as the desired tube (step 1), we next choose our circuit (step 2). Because the driver stage is on a separate chassis, link coupling is desirable. Consequently, the circuit of Figure IB is chosen.

3. The power input is 500 watts under the following typical ICAS conditions given in the tube data:

DC Plate Voltage	2250	volts
DC Grid-No. 3 Voltage	0	volts
DC Grid-No. 2 Voltage	400	volts
DC Grid-No. 1 Voltage	—155	volts
Peak RF Grid-No. 1 Voltage	275	volts
DC Plate Current	220	ma
DC Grid-No. 2 Current	40	ma
DC Grid-No. 1 Current (approx.)	15	ma
Driving Power (approx.)	4.0	watts
Power Output (approx.)	375	watts

4. The peak plate voltage is 1910 volts (2250 x 0.85).

5. The plate load resistance, obtained from the Nomograph, is about 4900 ohms.

6. Also from the Nomograph, the reactances X_C and X_L required for a plate load of 4900 ohms at 40 meters are 800 ohms for each section of the plate tank, and 400 ohms for the grid tank.

7a. Figure 3 shows that: (1) The capacitance of *each section* (C_P) of the split-stator plate-tank capacitor is 27 $\mu\mu$f at the mid-frequency. A capacitor of 50 $\mu\mu$f (each section) should be used to provide adequate band coverage. (2) The inductance of *each section* of the plate-tank inductor is 17 μh.

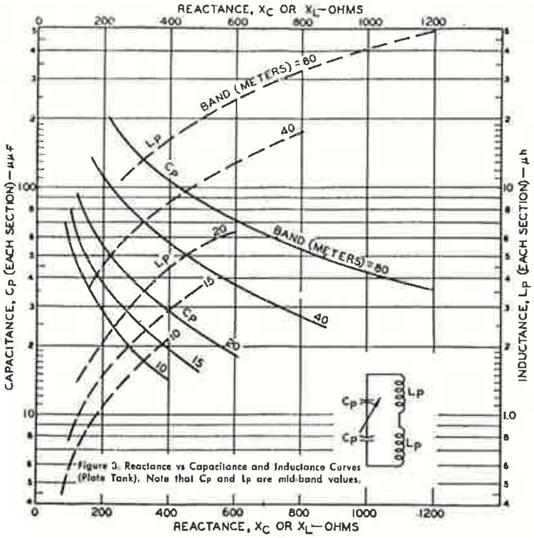


Figure 3. Reactance vs Capacitance and Inductance Curves (Plate Tank). Note that C_P and L_P are mid-band values.

7b. Figure 4 shows that: (1) The capacitance of the grid-tank capacitor is 55$\mu\mu$f at the mid-frequency. A capacitor of 100 $\mu\mu$f should be used to provide band coverage. (2) The inductance of the grid-tank inductor is 8.9 μh.

8a. Figure 8 shows that rotor-to-stator spacing for each section (C_P) of plate-tank capacitor for a peak rf plate voltage of 1910 v = 0.06″, minimum. (For telephony service, the peak rf plate voltage is 2 x 1910 v = 3820 v, and the spacing would be increased to 2 x 0.06″ = 0.12″, minimum.)

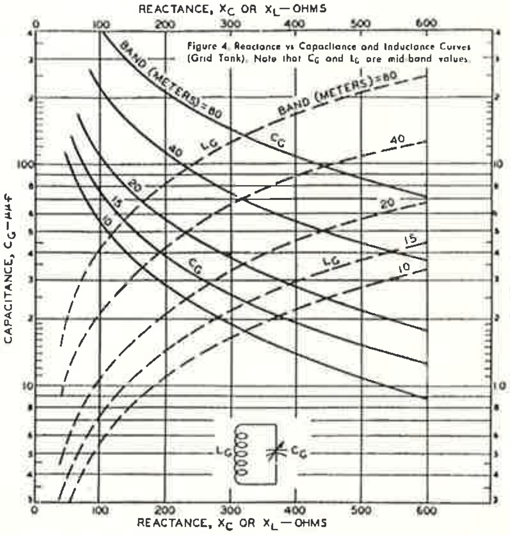


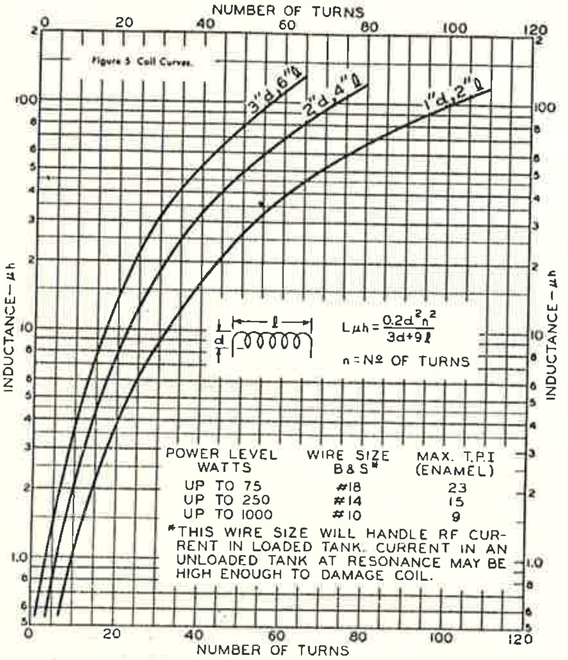
Figure 4. Reactance vs Capacitance and Inductance Curves (Grid Tank). Note that C_G and L_G are mid band values.

8b. Figure 8 also shows that rotor-to-stator spacing of grid-tank capacitor (C_G) for a peak rf grid voltage of 275 v = 0.01″, minimum distance (approximately).

9a. Step 7a showed that the plate tank inductance required is 17 μh for each section, or a total inductance of 34 μh. Referring to Figure 5, we find curves for 1-inch, 2-inch, and 3-inch diameter coils. The table of wire-sizes shows that No. 10 wire is suitable for a tank coil used in conjunction with a tube having a 375-watt power output.

The Wire Table in Figure 5 shows that the maximum number of turns per inch for No. 10 wire is 9 turns. Referring next to the curves in Figure 5 (for three representative coil-form dimensions), we find that an inductance of 34 μh requires 56 turns on a form having a 1″ diameter and a 2″ length, 41 turns on a form of 2″ diameter and 4″ length, and 32 turns on a form 3″ in diameter and 6″ in length. However, we have already noted that no more than 9 turns per inch can be wound with No. 10 wire, so it is clear that the coil form of 3″ diameter and 6″ length is the only one of the three which allows the necessary number of turns of No. 10 wire for an inductance of 34 μh. (For the experimenter willing to design coils using coil forms other than those used for the curves in Figure 5, the equation shown with the curves will be of value.)

9b. Step 7b showed that the grid-tank inductance required is 8.9 μh. Referring to Figure 5 again, with a tank inductance of 8.9 µh, and with #18 wire (suitable for power levels below 75 watts). we find that 30 turns on a 1-inch coil diameter and a 2-inch winding length provide the inductance required.



10. From the circuit shown in Figure 1B and from the "Miscellaneous Circuit Components Chart," Figure 6, we find that the following additional components, with indicated ratings, are required:

CAPACITORS

Capacitance	Working Voltage Volts (Minimum)	Type
Bypass:		
Filament, C_F		
0.001 to 0.01 µf	200	Disc Ceramic
Grid-No. 1, C_{G1}		
0.001 µf	200	Disc Ceramic
Grid-No. 2, C_{G2}		
0.001 to 0.005 µf	400	Disc Ceramic
Plate, C_B		
0.001 µf	2250	Mica
Neutralizing, C_N:		
0.5 µµf max.	4500	Variable-Air

RF CHOKES

Inductance mh	Current Rating Ma (Minimum)	Type
Plate:		
2.5	220	Any
Grid No. 1:		
2.5	15	Any

That's all there is to it. You've designed a complete final stage, to the required specifications. If you're in a rush to get "on the air", you can stop reading right now and plug in your soldering iron. The balance of this article is a discussion of the various charts and tables, with some thoughts on plate tank circuits in general.

Basic circuits

The circuits discussed in this article were selected for the following reasons:

1. They are very popular.
2. They are easily adjusted and require no special balancing. Neutralization is simple and straightforward.
3. All components can be easily obtained, and are available in great variety at relatively low cost.
4. There is less likelihood of TVI from single-ended balanced tank circuits than there is from the average push-pull amplifier.
5. A balanced tank circuit with link coupling allows easy installation of a low-pass filter designed to work on 50- or 75-ohm lines.

The Nomograph

The Nomograph (Figure 2) provides a simple method for solving a set of equations with reasonable accuracy. It indicates the proper plate load for any tube operating at a power level between 10 and 1000 watts and at dc plate voltage between 165 and 3500 volts. The Nomograph also relates "plate load" and "operating frequency" to the proper value of capacitive and inductive reactance required in the tank circuit. (It is important that the reactances X_C and X_L, along with loaded Q, be the specified values, to ensure proper plate loading and good circuit efficiency.) The Nomograph, used in conjunction with the single-ended balanced tank circuits shown in Figures 1A and 1B, also aids in the selection of a tube suitable for use with these circuits, as discussed under "Tube Selection".

To permit the use of practical values of tank C and L over the amateur bands from 80 through 10 metres, the Nomograph has been designed so that suggested values of loaded tank Q vary with the amateur band being used (Q increases with frequency).

Plate tank circuit considerations

As mentioned in "Tube Selection", the minimum value of the tuning capacitor is an important consideration for operation at the higher frequencies. It is good engineering practice to select a capacitor having the lowest possible minimum capacitance because, whenever circuit constants are such that the tube output capacitance becomes a major consideration, a capacitor of low minimum value will allow more flexibility in the choice of the amplifier tube.

Regarding tuning-capacitor range, calculations show that, for tuning the amateur bands, the maximum percentage change in capacitance from the value at mid-frequency is approximately ±15%. As a safety factor, a tuning capacitor having a minimum tuning range of ±30% should be adequate. Before testing a new amplifier, it is advisable to use a grid-dip oscillator to check the tuning range of each tank circuit with tubes in their sockets but no voltage applied.

Neutralization

Most class-C amplifiers must be neutralized in order to prevent self-oscillation. Triodes always require neutralization when used in the circuits shown in this article, whereas beam power tubes or pentode tube types may require neutralization or may not.

When input and output circuits of beam power tubes or pentode tube types are effectively isolated and good bypassing is employed, it is generally not necessary to provide for neutralization. However, it is difficult to build such an amplifier and, therefore, many amateurs are confronted with the problem of a self-oscillating amplifier when a new final is tested. Because the inclusion of a small neutralizing capacitor during the building of a new amplifier is a comparatively simple task, the capacitor is a worthwhile addition in view of its contribution to stable operation.

Neutralizing capacitors required for beam power tubes and pentode tube types are usually on the order of $\frac{1}{4}$ μμf. If it should prove difficult to obtain a neutralizing capacitor of this low value, it is a simple matter to construct your own. The capacitor shown in Figure 7 is variable from about 1 μμf to 0.06 μμf, and will be adequate for most beam power tubes or pentodes. For those wishing to design their own neutralizing capacitor, the equation $A = 4.5\,Cd$ is suitable, where A is the area of one plate in square inches; C is in μμf (approximately twice the grid-No. 1-to-plate capacitance is an appropriate value); and d is the distance between plates in inches (see Figure 8 for minimum spacing).

Figure 6. Miscellaneous circuit-components chart.

CAPACITORS

Value	Minimum DC Working Voltage — Volts		Type
	Telegraphy	AM Telephony	
COUPLING, C_C			
0.0001 μf	E_{bb} of driver $+E_{g1}$ of driven stage	E_{bb} of driver $+E_{g1}$ of driven stage	Variable, air; or fixed mica
BYPASS:			
Filament, C_F			
0.001—0.01 μf	200	200	Disc ceramic
Grid No. 1, C_{G1}			
0.001 μf	E_{g1}	E_{g1}	Disc ceramic
Grid No. 2, C_{G2}			
0.001—0.005 μf	E_{g2}	2 x E_{g2}	Disc ceramic
Plate, C_B			
0.001 μf	E_{bb}	2 x E_{bb}	Disc ceramic
NEUTRALIZING, C_N			
2 x Grid No. 1—plate capacitance (Max.)	2 x E_{bb}	4 x E_{bb}	Variable, air

RF CHOKES

Value	Current-carrying Capacity	Type
GRID		
2.5 mh (Approx.)	At least I_{g1}	Any
PLATE		
2.5 mh (Approx.)	At least I_p	Any

Figure 7. Small neutralizing capacitor.

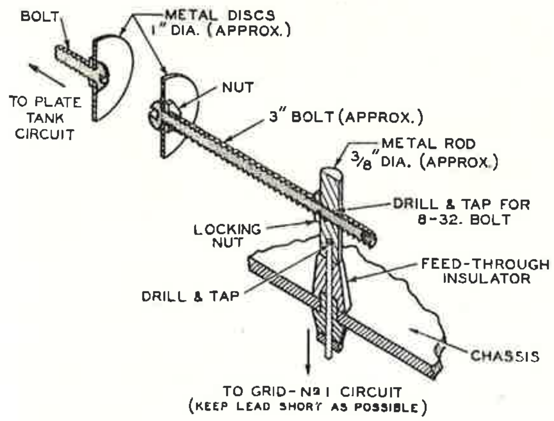
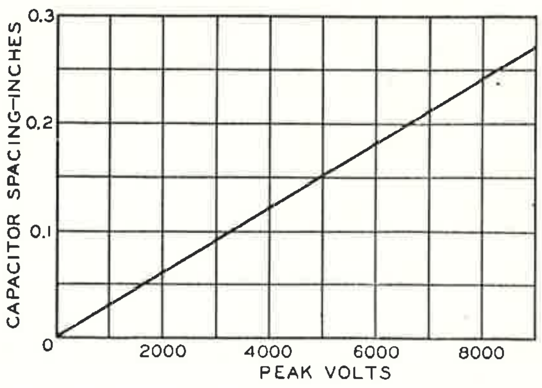


Figure 8. Capacitor-spacing Graph.



See improved method on P.98.

GRAPHICAL METHOD FOR CALCULATING THE RESULTANT OF TWO RESISTANCES IN PARALLEL

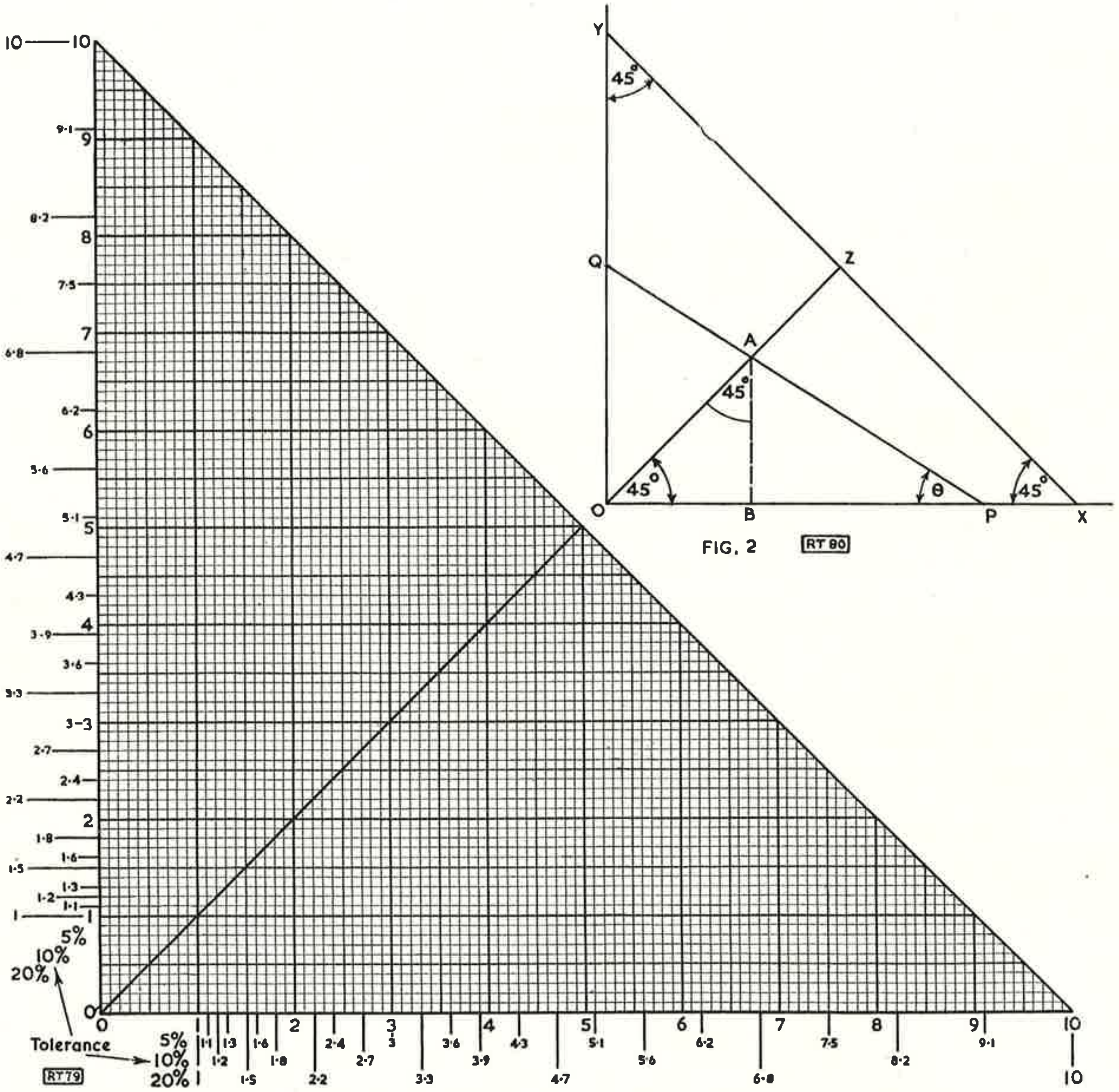
By F. LANGFORD-SMITH

A graphical method of calculating the resultant resistance of two resistors in parallel is well known (Ref. 1). The method given here is quicker to use, and has been elaborated to indicate the nearest "standard" value of resistance in accordance with the usual 5%, 10% and 20% tolerances.

This method was developed by Mr. A. A. Campbell, Communications Officer, The Forestry Office, 146 Canterbury Road, Canterbury, N.S.W., and is published with his kind permission.

The procedure is very simple. Mark the value of one resistor as point P on the X scale of Fig. 2.

FIG. 2 RT 80



RT79

Fig. 1. Graphical method for determining the resultant of two resistances in parallel (RT79). See article on opposite page.

Fig. 2. Illustrating method of using Fig. 1. See text.

then mark the value of the other resistor as point Q on the Y scale. Join PQ by a straight line which cuts the 45° line OZ at point A. Then drop a perpendicular line AB to give the resultant indicated by point B.

The scales as drawn are suitable for use with the greater of the two components between 1 and 10 ohms. If it is more than 10 ohms, both components should be divided by a suitable power of 10 to bring it within these limits, and the resultant should then be multiplied by the same power of 10.

This may be applied directly to all cases where the resultant is in the form

$$X = \frac{P.Q}{P + Q}$$

including inductances and reactances in parallel.

Appendix

For those who are interested, we give below the method of checking for fundamental accuracy.

It is required to prove that

$$OB = \frac{OP.OQ}{OP + OQ}$$

$$\text{i.e. that } OB = \frac{OP.OP \tan\theta}{OP + OP \tan\theta}$$

$$\text{i.e.} \quad OB = \frac{OP \tan\theta}{1 + \tan\theta}$$

$$\text{i.e.} \quad \frac{OB}{OP} = \frac{\tan\theta}{1 + \tan\theta}$$

$$\text{i.e.} \quad \frac{OB}{OB + BP} = \frac{\tan\theta}{1 + \tan\theta}$$

$$\text{i.e.} \quad \frac{OB + BP}{OB} = \frac{1 + \tan\theta}{\tan\theta}$$

$$\text{i.e.} \quad 1 + \frac{BP}{OB} = \frac{1}{\tan\theta} + 1$$

$$\text{i.e.} \quad \frac{OB}{BP} = \tan\theta$$

which is correct, since $\tan\theta = \frac{AB}{BP} = \frac{OB}{BP}$ since $OB = AB$.

Reference

1. Radiotron Designer's Handbook, 4th ed., p. 132, Fig. 4.10.

MINIMUM AUDIBLE CHANGE IN POWER OUTPUT

By F. LANGFORD-SMITH

A change in level of somewhat under 1 decibel is perceptible to the ear, when listening to a pure tone at 1000 c/s, if the change is made instantaneously. When listening to a programme source such as music, a larger change in level occurs before it is perceptible to the ear. Peterson and Beranek state that 3 decibels change "is usually significant" while 6 decibels is "usually worthwhile" (ref. 1). The author is of the opinion that 3 db is more than what most people regard as the minimum significant change, and suggests 1.5 db as a more satisfactory figure. This supported by the fact that the highest step used in studio attenuators is about 1.5 db.

The following table has been prepared on this basis, giving the minimum significant change in power output, based on 10 watts.

db	—7.5	—6	—4.5	—3	—1.5	0	+1.5	+3	+4.5	+6	+7.5	+9
watts	1.8	2.5	3.5	5	7	10	14	20	28	40	56	80

Thus an increase from 10 to 14 watts may be regarded as the minimum significant change in power output.

Reference

(1) Arnold P. G. Peterson and L. L. Beranek, "Handbook of Noise Measurement", published by the General Radio Company, 1953.

SQUARE WAVE TESTING

ADDITIONAL NOTES

The article on this subject in Radiotronics (June, 1955, page 65) showed an output potentiometer with an impedance of 5000 ohms. It is not advisable to increase this resistance, particularly when feeding into the input terminals of an amplifier, because of the bad effect on the waveform. An amplifier has quite an appreciable capacitive component in its input impedance and this, together with strays, may be enough to spoil the waveform when a higher resistance potentiometer is used.

A square wave has quite large harmonics at frequencies of more than 20 times the fundamental frequency, going into the range above 100 Kc/s with a 5 Kc/s applied square wave. For this reason also the leads between the square wave generator and the amplifier should be kept short.

Noted on original article. ✓

36.

AWV