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RADIOTRONICS

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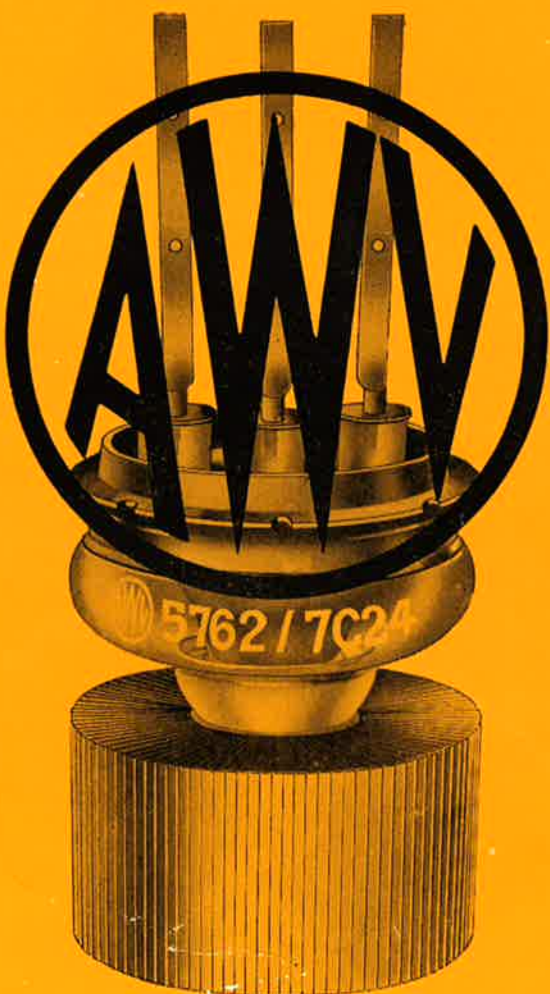

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AMALGAMATED WIRELESS VALVE COMPANY PTY. LTD.

EDITORIAL

In this issue we are pleased to publish a most important article on the subject of pickup output ratings which will undoubtedly be a "classic" on this all-too-little-known subject. Thanks to a simple formula and two large tables including most of the world's well known pickups, it is a simple matter for anyone to calculate the maximum output voltage from a particular pickup, and thus to choose a pre-amplifier to suit. Or the approach may be reversed and a pickup chosen to suit a particular pre-amplifier.

The designers of pre-amplifiers will also find much meat for consideration, in having to provide for high maximum input voltages without excessive distortion.

Shorter articles include one on sub-harmonics and some additional comments on the effect of damping in reducing loudspeaker distortion.

Last, but not least, a useful article on the design of single-ended Class C amplifiers.

In our next issue we hope to include another article in the series "Modern Methods of Testing Amplifiers", this one being on Harmonic Measurement using the Wave Analyser. Although these instruments are too expensive for widespread use, they are the only instruments capable of accurate measurements at very low degrees of distortion, and this article should be read by all those having any interest in a.f. amplifiers. What many engineers may fail to realize is that a Wave Analyser has a certain inherent distortion (second and third harmonics) which can only be side-stepped by the use of a high-pass filter when measuring the harmonics.

In a later issue it is anticipated that an article will appear on the measurement of distortion using a Total Distortion Meter.

Another future article will be on the very low distortion laboratory amplifier with a high input impedance and cathode follower output which has been built specially for measurements with the Wave Analyser or Total Distortion Meter. It may be used for measurement on any intermediate stage in an amplifier or pre-amplifier.

Arthur J. Gabb.

CONTENTS

Single-Ended Class-C Amplifier Design

by Clarence A. West, W2IYG

RCA Tube Division, Harrison, N.J.

The July-August, 1954, HAM TIPS gave a simplified procedure for the design of pi-coupled amplifiers. Now, W2IYG steps forward to discuss simplified design for single-ended Class-C amplifiers using balanced plate tank circuits.

Although much of the material presented here has been published piecemeal in one form or another, W2IYG has gathered the important considerations into this one article and boiled them down into simple, practical form.

The basic circuit for single-ended Class-C amplifiers is essentially the same regardless of the tube type used; the chief problem confronting the designer is the selection of the proper component values for this circuit. The tuned circuits present the greatest difficulty, especially for those who plan to make their own coils and select capacitors suitable for use with these coils. The selection of other circuit components may also pose problems.

This article presents a "rule-of-thumb" approach to the selection of components for use in the circuits shown in Figures 1A and 1B. This approach, which eliminates the use of formulas and equations, provides workable circuits having adequate efficiency for most "ham" uses. A nomograph and a series of charts and curves enable the designer to determine quickly the value and rating of all circuit components including the physical constants of the coils. The step-by-step design procedure is as follows:

1. Select a suitable tube type.
2. Select a circuit, Figure 1A or 1B.
3. Select tube power output from tube data.
4. Determine peak plate voltage by multiplying dc plate voltage by 0.85.
5. On Nomograph, Figure 2, place straightedge on these values of power output and peak plate voltage. Read "Plate Load" value.
6. Place straightedge from this plate load value to the "Amaeur Band" desired. Read "Reactance X_C and X_L" value.
7. In Figures 3 and 4, *Reactance vs Capacitance and Inductance Curves,* read the values of tank capacitance and tank inductance required.
8. Determine minimum capacitor spacing, from Figure 8.
9. From Figure 5, *Coil Curves,* determine diameter, length, number of turns, and wire size required.
10. From Figure 6, *Miscellaneous Circuit Components Chart,* select values of other circuit components.

Before we run through a typical example, it is worth while to consider the important factors which influence tube selection.

Tube selection

The selection of a tube to be used in the circuits covered by this article should not be made on the basis of tube power output alone. Equally important factors are: (1) tube output capacitance; (2) plate load; (3) driving power.

Tube output capacitance. This capacitance is added to the tank-circuit capacitance — thus changing the tank circuit's resonant frequency. At the lower frequencies this increase in tank capacitance is not serious, because the ratio of the tuning capacitance to the tube output capacitance is reasonably high. Thus, the tuning capacitor may be adjusted slightly to compensate for the tube output capacitance. At the higher frequencies, however, this capacitance ratio decreases and it may not be possible to reduce tuning capacitance sufficiently to obtain resonance within the band.

Plate load. A survey of popular power tubes used by amateurs reveals that most of them have

Figure 1. Basic Circuits. (When triodes are used, omit Grid-No. 2 and Grid-No. 3 circuitry.)

1A. Capacitance coupling from driver. **1B. Link coupling from driver.**

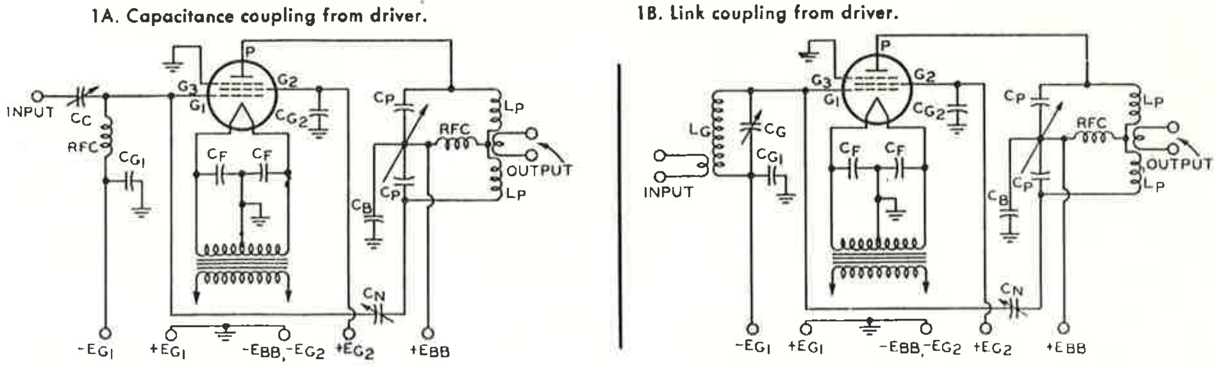

Figure 2. Nomograph.

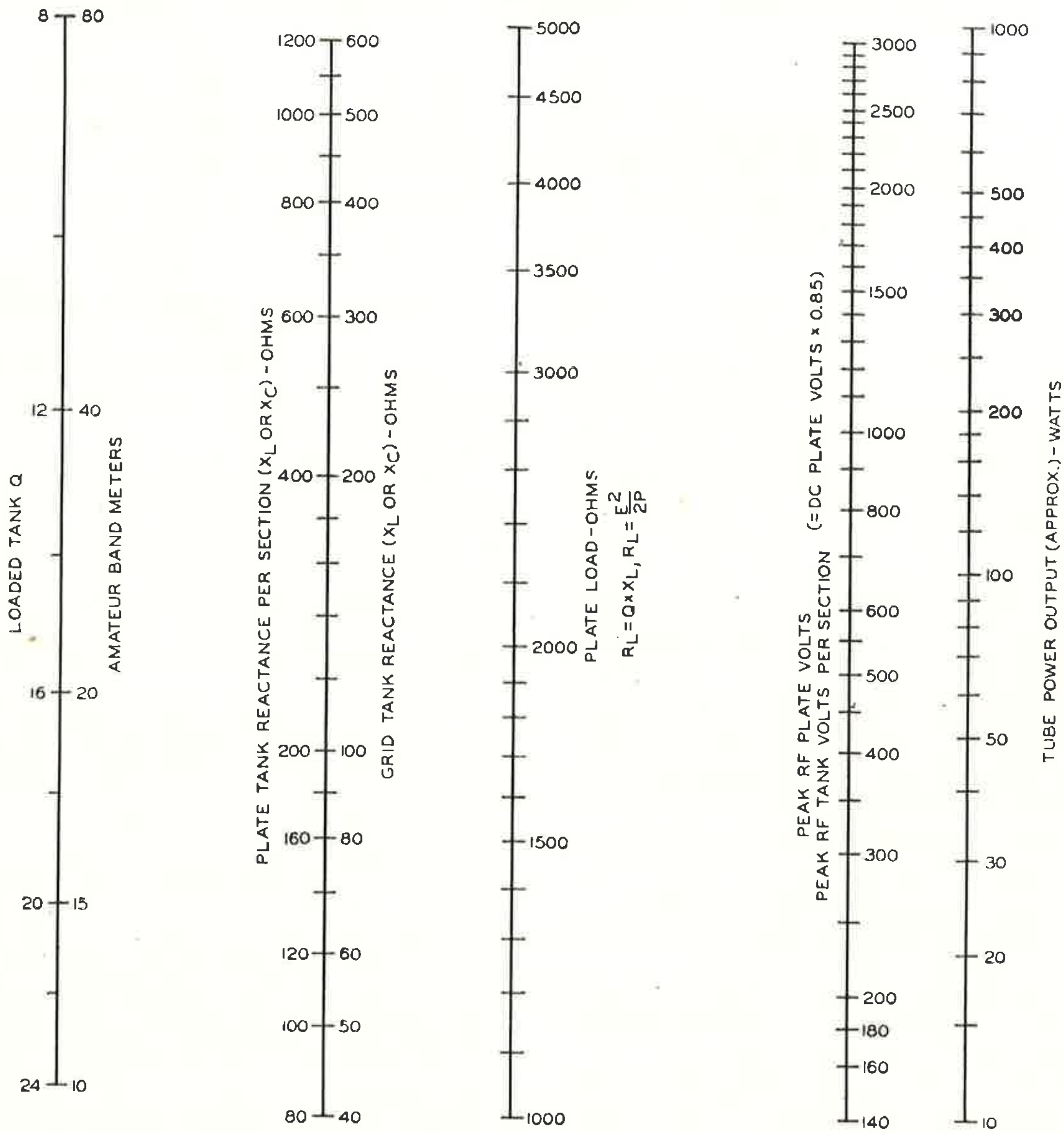

plate load resistances in the range between 2500 and 5000 ohms. The Nomograph can be used for all popular types because it covers resistance values from 1000 to 5000 ohms. If the selected tube has a plate load resistance in excess of 5000 ohms, parallel operation of two or more lower-power tubes should be considered. The plate load resistance may also be reduced by operating the tube at a lower plate voltage and a higher plate current.

Driving power. The power output from the driver stage should be at least twice the grid driving power required by the driven tube. When sufficient driving power is available, the selection of a triode greatly simplifies circuit design because triodes in general have low output capacitances, are easy to neutralize, and have a plate load resistance of approximately 3500 ohms. In addition, grid-No. 2 and grid-No. 3 considerations are eliminated.

Typical design problem

The following sample design problem can easily be solved with the aid of the Nomograph, charts, and curves.

Problem: To design a 500-watt input class-C amplifier for CW telegraphy service, having a single-ended, balanced, plate tank circuit and a tuned grid-input circuit, for operation on 40 metres. Power output from an available driver stage is about 10 watts.

Procedure: Refer to a technical booklet such as the "RCA Headliners for Hams" (Form No. HAM 103B), which lists popular RCA types for amateur use. With the aid of such a publication, we find that a beam power tube or a pentode (for example, type 813) fits the driving-power requirements for the plate input involved.

(This article will be concluded in the next issue.)
Continued on P.31.

PICKUP OUTPUT RATINGS AND RECORDING LEVELS WITH COMMENTS ON THEIR EFFECT ON PRE-AMPLIFIERS

See also P.70 re Pre-Amp. Sensitivity.

By F. Langford-Smith

Existing methods of rating pickups for output level have produced a condition approaching chaos.

In many cases the output is stated as so many millivolts (or dbm) from a specified frequency test record. In some cases the recorded level is quoted, but in the other cases it is left for the user to find out. In one such case the writer was left in the dark because the specified test record only gave relative levels, and no actual recorded velocity.

In any case, all these methods put quite unnecessary difficulties in the path of the would-be user. Surely it is much more satisfactory for a pickup to be rated as 12 millivolts per centimetre per second recorded velocity than to say that it has an output of 38 millivolts at 3.16 cm/sec. r.m.s. The latter value cannot be used directly, since nearly all standard frequency records are recorded at levels appreciably lower than ordinary records, and it is very confusing because of the large differences between recorded levels in the various frequency test records.

This raises the question, what recorded velocities are used by the various manufacturers? If this is known, the maximum output of the pickup on a particular record is given by

Pickup output (mV) = Rating x max. recorded velocity .... (1)

where rating = output expressed in millivolts/cm/sec., and

max. recorded velocity is the maximum level on the record concerned, expressed in centimetres per second, r.m.s.

The reason why we are concerned with the maximum recorded velocity on a particular record is that it affects both amplifier and loudspeaker overloading. It is really the limiting factor.

Unfortunately records cover a very wide range of levels. However, through the courtesy of Mr. W. Buckland, of E.M.I. (Australia) Pty. Ltd., and the manufacturers of Ronette Pickups, we have been given a range of maximum velocities occurring in individual records from various manufacturers in several countries. This range is set out below:

Minimum 5 cm/sec. r.m.s. (Buckland).

Maximum 30 cm/sec. r.m.s. (Ronette).

This range covers both microgroove and standard records, and refers to the maximum velocity actually recorded, at any frequency. Usually the highest velocity occurs at a high frequency, due to the pre-emphasis. We understand that the maximum value normally used by E.M.I. in Australia is 10 cm/sec., while occasionally a level of about 15 cm/sec. may be reached.

It is also necessary to consider the effects of tolerances in pickup output voltage at 1000 c/s. Some manufacturers publish tolerances of the order of ±2db (i.e., +26%, −21% in voltage output) but there seem to be grounds for suspecting that the tolerances in other makes are considerably higher. We have adopted, for design purposes, a tolerance of ±33% but it should be remembered that occasional pickups may come outside these arbitrary limits.

Applying both these tolerances to eqn. (1) we have

Minimum pickup output =
(rating −33%) x 5 cm/sec. r.m.s.

Maximum pickup output =
(rating +33%) x 30 cm/sec. r.m.s.

Thus, unless an equalization network is used between the pickup and the grid of the first valve in the pre-amplifier, there is a possible range of about 12 to 1 in the voltage applied to the grid of the first valve, when using records from different sources.

We would be happy to publish any other relevant information on this subject, and would welcome correspondence from those able to assist.

Tables 1 and 2 give the output ratings (in mV/cm/sec.) of a wide range of pickups of English, American, Australian and European manufacture. If any other pickup manufacturers care to supply the necessary information, we would be happy to publish a supplementary list. See P.125 For this.

Types other than crystal or ceramic

Table 1 covers all types other than crystal or ceramic. In most of these the rating, although quoted for 1000 c/s, is substantially constant over a wide frequency range. The "ideal" velocity-operated pickup gives a constant rating (mV/cm/sec.) at all frequencies, and some of the better quality pickups in Table 1 approach this ideal very closely over the whole audible range, say from 30 to 15,000 c/s.

In most home installations using these types of pickups there is no equalizer or attenuator between the pickup and the grid of the first valve, so in these cases there are no complications. For this type of installation the peak input voltage to the grid of the first valve will be simply 1.41 times that given by eqn. (1), and in the extreme case quoted above the maximum recorded velocity is to be taken as 30 cm/sec. It is important to ensure that grid current does not flow in the first valve under these conditions, and that all valves, out of a fairly large test batch, are free from grid current.

The conditions regarding overloading in the first valve become more onerous if any one of a wide range of pickups may be used. In this case the worst condition is with the most sensitive pickup, allowing for pickup tolerances, and the highest recorded level (30 cm/sec.), and grid current must be avoided with all the valves in the test batch.

Pentodes more readily permit adjustment of the operating conditions without serious reduction in performance, using higher screen and negative bias voltages. High-mu triodes may present a serious problem, and a lower mu may be desirable. A possible alternative is to use a high-mu triode with a pad having fixed attenuation between the pickup and the input terminals, but this will reduce the signal to noise ratio. Another alternative, used by Baxandall (Ref. 1) switches the first valve from triode to pentode operation. In both these special cases the operating procedure is to use the low gain position unless the overall gain is insufficient.

In many studio installations there is a passive equalizer between the pickup and the input to the preamplifier, giving an attenuation of the order of 24 db. In such cases only a single type of pickup is used in each channel, so that it is possible to calculate or measure the output voltage from the equalizer, on each setting of the equalization control, with both maximum and minimum recorded velocities.

Crystal and ceramic types

Table 2 covers crystal and ceramic types. For these cases, the application of the principles stated above for all types of electro-magnetic types is complicated by the fact that the output voltage from the pickup varies considerably with frequency. In most cases the maximum voltage is greater than that at 1000 c/s.

A further point of difference is that the general output level is much higher than that with electro-magnetic types. Consequently the best arrangement seems to be to insert the volume control between the pickup and the grid of the first valve. By this means, grid current in the first valve does not occur at a lower level than the general overload point of the amplifier.

To use the information in Table 2 for frequencies other than 1000 c/s, the pickup rating for any frequency f is given by the rating from Table 2 (in mV/cm/sec.) multiplied by a factor F where

$$F = \frac{\text{output voltage at frequency } f}{\text{output voltage at 1000 c/s}}.$$

In practice all that is necessary is to note on the response curve the difference in level in decibels between 1000 c/s and frequency f, and to convert this to a voltage ratio which is the required factor F. When the response at a frequency f is greater than that at 1000 c/s, then the factor F will be greater than unity (see Examples).

It is important to remember that the low frequency response of a crystal or ceramic pickup is influenced by the load resistance, and particularly by a load resistance less than 1 megohm.

General remarks

Values tabulated are those for operation with the optimum load resistance, as recommended by the manufacturer.

In all cases the output quoted in the tables is that from the pickup without the use of an equalizer.

Examples

(1) Take the A.W.A. pickup, 5000 ohm model. From Table 1 the rating is 5.5 mV/cm/sec. at 1000 c/s. Using eqn. (1) we have

Pickup output = 5.5 (5 to 30) mV
Minimum output = 5.5 x 5 = 27 mV
Maximum output = 5.5 x 30 = 165 mV.

But it is also necessary to allow for pickup tolerances, the suggested design value being ±33%. Hence the spread between maximum and minimum is increased, giving

Minimum output = 27 x 0.67 = 18 mV
Maximum output = 165 x 1.33 = 22 mV.

In designing a pre-amplifier for this pickup to work directly on to the input terminals, the gain and signal/noise ratio must be satisfactory for an input of 18 millivolts, while it must be also capable of handling an input of 220 millivolts without excessive distortion. The ratio between these extremes is 12:1, thus making the design of a satisfactory pre-amplifier rather difficult.

It is suggested that the geometrical mean between these extremes might be adopted as a design mean — in this case it would be 62 millivolts.

If the response of such a pickup is not quite constant with frequency, it would be possible to determine the frequency at which the response (mV/cm/sec.) is a maximum, and to find the factor F by which the rating at 1000 c/s should be multiplied, following the same principle used for crystal and ceramic types above. Any variation in the response at the low frequency end could well be neglected, because normally treble pre-emphasis leads to overloading at the top end. With pickups in this general group the results achieved are quite definite and accurate, being simplified by the almost constant output for constant applied velocity.

(2) Take the Ronette TO-284-0V crystal pickup as a typical case, on LP. The object of the investigation is to determine the frequency at which the highest input voltage is likely to occur when used with any normal type of programme, and the difference in response between that at such a frequency and that at 1000 c/s.

In Fig. 1 curve 1 is the pickup response as published by the manufacturers, using a Decca LP Standard Frequency Record (i.e., one which follows the Recording Characteristic) whose characteristic is shown in curve 2. Curve 3 is the difference between curves 1 and 2, plotted with 1000 c/s as the reference level (0 db). Curve 3 is the response which the pickup would have if used on a constant velocity record. Its greatest response under these conditions occurs at about 150 c/s, where it is over 10 db above that at 1000 c/s. This is the equivalent of the result achieved above for an electro-magnetic pickup (Example 1) but it obviously does not give the information sought.

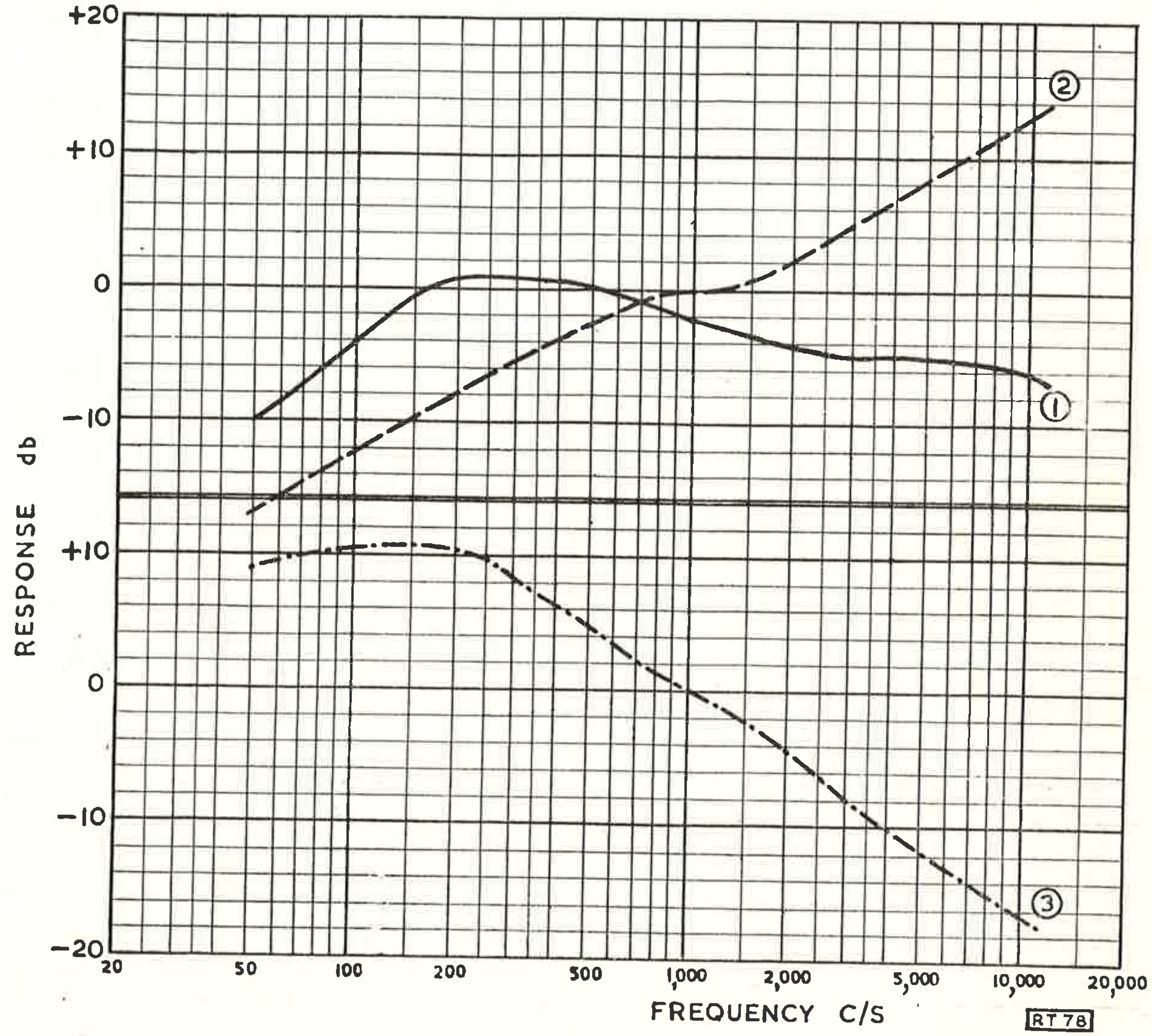

Fig. 1. Curve 1: Ronette TO-284-OV pickup response with load resistance 500,000 ohms and Decca LP Standard Frequency Record (following the Recording Characteristic). Curve 2: Decca LP Standard Frequency Record (following the Recording Characteristic). Curve 3: Difference between curves 1 and 2, expressed in decibles, with 1000 c/s as reference level (0 db). This is the response which the pickup would have if used on a constant velocity record (RT78).

There is insufficient information available to draw any final conclusions for crystal pickups. Fortunately, if the volume control is placed between the pickup and the grid of the first valve, the maximum voltage delivered by the pickup is not of great importance. It seems likely that the published pickup response curve (Curve 1) when using a record with the standard Recording Characteristic, is the closest approach which can be made at present to the result. If this can be accepted, then Curve 1 shows that the peak occurs at about 250 c/s and is about 3 db (1.4 times) higher than that at 1000 c/s. Using Table 2, the rating for this pickup is 250 mV/cm/sec at 1000 c/s.

(*Continued on page* 23)

TABLE 1.—All types other than crystal or ceramic

Name	Model	Type	mV/cm/sec.*
Altec-Lansing (America)	Information not available		Note 1
Audax (America)	D-L-6 Chromatic Hi-Q7 Chromatic L-6 Chromatic	EM EM EM	2.4 4.4 2.6
A.W.A. (Australia)	30,000 200 ohms 5000 ohms	EM EM	2.0 5.5
Chancery (England)			
Clarkstan (America)	201 RV 204 RV	EM EM	4 2
Connoisseur (England)	Mark I 25 ohm Mark II 400 ohm	EM EM	3.3 2.5
Decca (England)	X/M/S Gold Std. LP X/M/S Red Std. LP X/M/S Silver Std. LP X/M/S Green Std. LP H Gold LP H Black LP	EM EM EM EM EM EM EM EM EM EM	1.7 1.0 5 3.3 12.5 6.7 25 22.5 2 13
Electro Sonic Laboratories (America) (Danish origin)	Professional Concert Soloist	MC MC MC	0.11 0.08 0.11
E.M.I. (England)	17 200 ohms transf. high imped. transf. 17A with 1:110 transf.	EM EM EM EM	0.56 7.5 0.11 12
Fairchild (America)	215A†, 215B†, 215C†,	MC	0.4
Ferranti (England)	220A, 220B, 220C with own transformer	MC Ribbon	0.8 1
G.E. (variable reluctance) (America)	Home Type Broadcast types	EM EM	2.2 1.7
Goldring (England)	200 500	EM EM	160 3.2
Leak (England)	Old (with transformer) New (with 1:80 transformer)	MC MC	20 8
Lowther (England)	Std. LP	MC MC	2.0 4.2
M.B.H. (Australia)	High impedance 600 ohms 200 ohms	EM EM EM	9.0 1.0 0.6
Orthofon (Denmark)	A B C	MC MC MC	0.5 0.4 0.3
Pickering (America)	D-140, S-140, D-120, S-120 220, 240, 260 350 series Fluxvalve	EM EM EM ?	5 3 2.5 3
R.C.A. (America)	Lightweight	EM	Note 1
Tannoy (England)	Variluctance Mark II	EM	2.2
Weathers (America)	W-202 W-400	FM FM	100‡ 160‡

* at 1000 c/s. Output from pickup unless otherwise stated.
† Replacement model.
‡ output from oscillator at 500 c/s.

EM = electro-magnetic (variable reluctance).
FM = frequency modulation.
MC = moving coil.
Note 1: Studio installation with inbuilt equalizer.

Amended ratings listed on P. 125.

TABLE 2.—Crystal and ceramic types

Name	Model		Type	mV/cm/sec.*
Acos (England)	GP19	Std.	Crystal	320
		LP	Crystal	280
	GP25, GP29	Std.	Crystal	220
		LP	Crystal	210
	HGP33, HGP35, HGP37	Std.	Crystal	320
		LP	Crystal	280
	HGP39, HGP41, HGP45	Std.	Crystal	320
		LP	Crystal	280
	HGP55, HGP57	Std.	Crystal	320
		LP	Crystal	280
	GP.59-1	Std.	Crystal	480
		LP	Crystal	420
	GP.59-3	Std.	Crystal	950
		LP	Crystal	830
	GP.61	Std.	Crystal	130
		LP	Crystal	83
Astatic (America)	16L3		Crystal	910
	51 series		Ceramic	160
	401A		Crystal	280
	402M		Ceramic	140
	403J		Crystal	160
	AC series		Crystal	200
	AC-C series		Ceramic	120
	CAC series		Crystal	160
	L-12		Crystal	800
	L-29		Crystal	600
	L-26A		Crystal	280
	L-40A		Crystal	120
	L-70A		Crystal	200
	L-72		Crystal	700
	L-74		Crystal	280
	L-82A		Crystal	700
	LQD series		Crystal	200
	U-J		Crystal	110
	QT series		Crystal	170
	66 series		?	680
	55-T series		Ceramic	160
B.S.R.	see under Acos.			
Collaro (England)	O		Crystal	190
	P		Crystal	48
	Transscription		Crystal	32
Decca (England)	Three-pin	Std.	Crystal	125
		LP	Crystal	140

Name	Model	Type	mV/cm/sec.*
Dual (Germany)	CDS2, CDS3, (Std.)	Crystal	62 min.
	CDS2, CDS3 (LP)	Crystal	72 min.
Electro-Voice (America)	80	Ceramic	96
	Power point	?	160
	12	Crystal	290
	32	Crystal	350
	42	Ceramic	190
	14, 16-TT	Crystal	190
	33, 34	Crystal	240
	43, 44, 46T	Ceramic	150
	47	Ceramic	120
	60	Crystal	770 or 390
	50	Crystal	480
	84	Ceramic	96
E.M.I. (England)	Ceramic cartridge	Ceramic	130
Garrard (England)	GC2	Crystal	440
	GC2/PA	Crystal	310
	GCE3 and GCE4	Ceramic	190
Ibbott (Australia)	Data not available	Crystal	
Philips (Netherlands)	AG3002,†, AG3003†	Crystal	70
	AG3005†, AG3006†, AG3007†	Crystal	170
	AG3008†, AG3105†, AG3106†	Crystal	170
	AG3010	Crystal	270
	AG3012, AG3013, AG3015	Crystal	83
Plessey (England)	Sonotone	Ceramic	110
Ronette (Netherlands)	TO-284-P	Crystal	120
	TO-284OV	Crystal	250
	TO-284-T	Crystal	660
	TO-284-TS	Crystal	970
	TO-395	Crystal	1130
	RA-284-OV	Crystal	220
	RA284-T	Crystal	600
	RA-395	Crystal	1070
Shure Bros (America)	W31AR	Crystal	650
	WC10	Ceramic	200
	W22AB	Crystal	300
	WC24	Ceramic	140
	W26B	Crystal	250
	WC38	Ceramic	230
	W70B	Crystal	1000
	W68	Crystal	350
	W78	Crystal	1100

† Replacement only.
* at 1000 c/s.

Pickup output at 1000 c/s = 250 (5 to 30 mV)
Minimum = 250 × 5 = 1250 mV = 1.25 V
Maximum = 250 × 30 = 7500 mV = 7.5 V.
Allowing for the increased response at 250 c/s, which affects the maximum only, we have:
Minimum = 1.25 V
Maximum = 7.5 × 1.4 = 10.5 V.
Allowing, in addition, for the pickup output tolerance, we have:
Minimum = 1.25 × 0.67 = 0.84 V
Maximum = 10.5 × 1.33 = 14 V
which gives a ratio of 16.7 times between these two extremes, compared with 12 times for the electro-magnetic case. The point of special interest is the large voltage which can be developed by a crystal pickup of average sensitivity.

(3) The same method of calculation as for Example 2 has been used to determine the values for a typical very high output crystal pickup, Ronette TO-284-TS, designed to operate directly into the grid circuit of an output valve. In this case, all the values are for 1000 c/s only.
Minimum = 970 × 5 × 0.67 mV = 3.25 V.
Maximum = 970 × 30 × 1.33 mV = 39 V.

Reference

1. Baxandall P.J. "Gramophone and microphone pre-amplifier" W.W. 61.1 (Jan. 1955) 8. This design uses the triode/pentode changeover in the microphone channel.

SUB-HARMONICS

By F. Langford-Smith

For many years it has been known that non-linear devices, such as loudspeakers under certain conditions (Ref. 1) produced sub-harmonics. The same effect can also occur in an amplifier in which there is considerable non-linearity. A sub-harmonic is a component of a complex wave having a frequency which is an integral sub-multiple of the basic frequency. For example, if the basic frequency is 100 c/s, its sub-harmonic frequencies would be 50, 33.3, 25, etc.

However, until very recently there was no satisfactory and widely accepted theory to account for the method of their generation, since the well-known Fourier analysis does not account for frequencies lower than the fundamental frequency. West and Douce (Ref. 2) have developed a theory for the mechanism of sub-harmonic generation in a feedback system. This theory has been developed for a feedback amplifier with both a linear element and a non-linear element and considers the input signal as a means of modulating the gain of the non-linear element. It is shown that the gain of the non-linear element is changed in both amplitude and phase for a sine-wave of frequency a fraction that of the input.

This effect makes the closed feedback loop unstable, the frequency of oscillation being a fraction of the input frequency. As an example, the cubic form of non-linearity is fully analysed, and it is shown that the sub-harmonic of frequency one-third that of the input frequency can occur if the phase lag of the linear system lies within the range 159-201°.

References

1. Radiotron Designer's Handbook 4th ed. p.871 (iv).
2. West, J. C., and J. L. Douce "The feedback sub-harmonic generation in a feedback system" Proc. I.E.E. 102 (Part B) 5 (Sept. 1955) 569. Summary, Jour. I.E.E. 1.9 (Sept. 1955) 602.

EFFECT OF DAMPING IN REDUCING LOUDSPEAKER DISTORTION ADDITIONAL COMMENTS

Since the article under this title on page 69 of our issue for June, 1955, was printed, there have been at least two articles criticising the rather startling results claimed by C. A. Wilkins, and pointing out that the improvement in reducing loudspeaker distortion only occurs with poor quality loudspeakers. Noted.

We believe that the criticism of Mr. Wilkin's results is justified.

"ULTRA LINEAR" AMPLIFIERS

Correction.

In the article under this title on page 70 of our issue for June, 1955, the two blocks, Fig. 1B and Fig 2B, were inadvertently transposed.

Fig. 1B as printed is for —21 volts bias, while Fig. 2B as printed is for —19 volts bias. Noted.

Editor .. .. A. J. Gabb, B.Sc.
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