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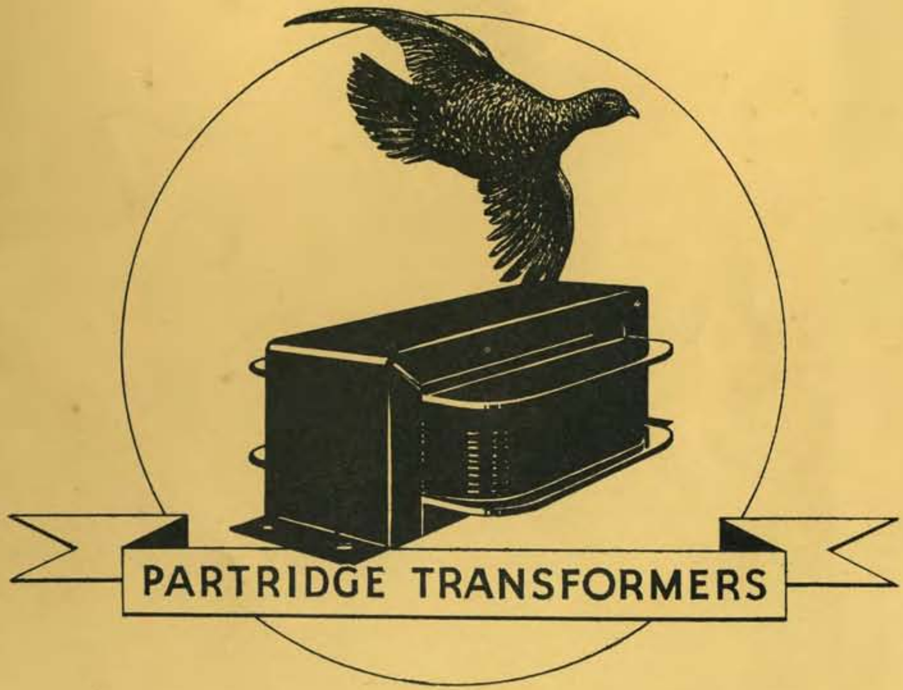
PARTRIDGE P. A. MANUAL

PRICE 2/6



N. PARTRIDGE, B.Sc., A.M.I.E.E.

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N. PARTRIDGE, B.Sc., A.M.I.E.E.

P.A. Consultant and Transformer Specialist

Foreword

by

J. P. McKENZIE, M.C., A.M.I.E.E., M.I.R.E.

Managing Director, Sifam Electrical Instrument Co. Ltd.

The opportunity of introducing a new edition of so popular a handbook is at once a source of pleasure and apprehension. The enthusiasm with which the original "Partridge P.A. Manual" was received makes redundant any attempt to enlarge upon the need for such a work, and it would be equally superfluous to eulogize its author as a public address engineer and transformer specialist of repute.

However, there is perhaps one aspect of Mr. Partridge's many qualifications that may not be known outside the circle of his more intimate acquaintances. P.A. is not only an applied science, but equally an applied art and therefore it is a matter of more than passing interest that Mr. Partridge is an executive musician of considerable attainment. A pupil of that brilliant virtuoso, the late Albert Fransella, his own ability as a flautist has been publicly recognized by gold and silver awards for the finest wood-wind solo performances at competitive London Music Festivals.

It is evidently no chance circumstance that finds Mr. Partridge in the position he occupies to-day, but rather the conscientious development of natural abilities followed by their successful application to the Service of Man.

J. P. McKENZIE, M.C., A.M.I.E.E., M.I.R.E.,
Managing Director,
SIFAM ELECTRICAL INSTRUMENT CO., LTD.

CONTENTS

AUTHOR'S INTRODUCTION

The implication that individual success was more easily achieved fifty years ago than at the present time meets too readily with tacit approval. One is told that every trade and profession is overcrowded and that public companies and combines make commercial success impossible for the small man. In reality these statements are veiled excuses for personal inertia that, if allowed to pass unchallenged, undermine the initiative by making failure a foregone conclusion.

So rapid is the growth of both science and art that fresh openings for the expression of individual ability are continually revealed. Indeed, owing to the distracting rapidity with which new interests arise, it is sometimes difficult to focus the attention upon those few activities for which one has a particular aptitude. The most common barrier to progress is lack of self confidence which is made evident by an inability to pursue a clear-cut line of action wholeheartedly and unerringly to its ultimate conclusion. The most carefully prepared plans are apt to go astray and failure usually brings unpleasant consequencies. How many refrain from action for fear of failure and in the mistaken belief that security lies in the avoidance of all risk ?

Life is hazardous in its beginning and is inevitably beset by attendant risk throughout its course. Nature has provided physical risks in abundance and to these civilisation has added those uncertainties associated with matters spiritual and financial. Confidence and courage lead to endeavour, endeavour to success, and success reacts as a potent tonic bringing renewed energy and a strengthened self-confidence.

* * * *

Public Address is peculiarly adapted to a small beginning, and as a profession offers wider scope than has as yet been appreciated. An idea of the diversity of its applications can be obtained from the Appendices II and III. To-day P.A. is often regarded (and rightly so !) as a public nuisance, but its possibilities are legion and to-morrow it will fulfil a true service to the community and be acclaimed one of the miracles of modern science. Those who face and survive the hazards of the intervening night will be adequately rewarded.

Very little capital is needed to acquire a small but complete P.A. equipment. The risk to which this capital is exposed can be reduced by acquiring a sound working knowledge of the subject, of its history, and of the pitfalls that others have already discovered. There are three essentials:—(1) Good reproduction; (2) low initial outlay; and (3) a thorough knowledge of the equipment. In the opinion of the author there is no better method of ensuring that these requirements are fulfilled than by building one's own amplifiers. This booklet in conjunction with its companion volume "Partridge Amplifier Circuits," will enable a strikingly high standard of reproduction to be attained at a price below that usually paid for mediocrity. Substantial justification for this claim has been accumulated from the many letters of appreciation received from readers who followed the advice proffered in the original edition of the "Partridge P.A. Manual."

ELECTRO-ACOUSTICS

Before considering the technicalities of electrical reproducers it will be as well to review briefly the nature of the sounds that one hopes to re-create.

Power Required:—The first question is how much power is radiated by various sources of sound? Table 1 provides the answer. The second column shows the peak power, expressed in R.M.S. watts, radiated in the form of sound waves by typical sources. Unfortunately, loud speakers have a poor efficiency and considerably more power has to be provided by the amplifier than is actually radiated by the speakers. Columns three and four indicate the undistorted power output needed from an amplifier to reproduce the original sounds at full volume when using exponential horns and baffle-mounted speakers respectively.

TABLE I.

Source of Sound.	Peak Power Radiated. R.M.S. Watts.	Amplifier Output Required to Radiate Equal Power.	
		With Exponential Horn Speakers. R.M.S. Watts.	With Cone Speakers on Large Baffles. R.M.S. Watts.
Normal Conversation ..	0·0005	0·0015	0·01
Piano	0·15	0·45	3·0
Cinema Organ	6·0	18·0	120·0
Small Orchestra	5·0	15·0	100·0
Symphony Orchestra ..	30·0	90·0	600·0
Flute	0·03	0·09	0·6
Trumpet	0·16	0·48	3·2
Cymbals	5·0	15·0	100·0
Bass Drum	12·0	36·0	240·0

The magnitude of the required power appears disquieting. Luckily, several factors arise to mitigate the situation:—(1) If the power is halved, the audible loss of volume is very small; (2) the powers stated are necessary only to accommodate the fortissimo passages and sforzando chords; these occur but rarely and instantaneous overloads can be tolerated occasionally; (3) these peaks are purposely reduced in gramophone recordings and radio transmissions in order to increase the ratio of average to peak power; (4) speakers can often be focused upon the audience, thus affecting an economy by saving the power that otherwise would be radiated uselessly into space. In practice an output of 30 to 45 watts is adequate for most purposes where baffle-mounted speakers are used, and only 6 to 12 watts for large exponential horn speakers.

The Decibel:—The loudness of sound is generally expressed in decibels, and Table 2, in conjunction with Fig. 1, will help to illustrate what this means. The decibel is a comparative unit and therefore, when stating that a certain sound intensity is say plus 20 db., it must also be stated or implied what standard is being taken for comparison. In Fig. 1 various noise levels are expressed in decibels and the quietest audible sound has been taken as the zero for comparison. Any other intensity could have been selected, and it would be equally correct to say that normal conversation is approximately 20 db. above average room noise and the threshold of hearing 40 db. below it.

A large number of experiments has shown that a reduction of 8 db. corresponds to what the average person would call "half as loud." Similarly, an increase of 8 db. sounds "twice as loud." Table 2 indicates that 8 db. represents a change of 6·3 times when expressed as a ratio of powers (watts). Thus an output of one watt will sound only about half as loud as an output of 6·3 watts.

Another interesting fact is that 3 db. is too small a change to be of any importance. For example, suppose the radio is playing and one goes out of the room for a few moments during which time the volume control is altered by 3 db. On returning to the room it will be quite impossible to state with certainty if the change has been an increase or reduction of volume, or indeed

TABLE II.

Decibels	Voltage or Current Ratio		Power Ratio		Decibels	Voltage or Current Ratio.		Power Ratio.	
	Up.	Down.	Up.	Down.		Up.	Down.	Up.	Down.
1	1·122	0·8913	1·259	0·7943	26	19·95	0·05012	398·1	0·00251
2	1·259	0·7943	1·585	0·6310	27	22·39	0·04467	501·2	0·00200
3	1·413	0·7080	1·995	0·5012	28	25·12	0·03981	631·0	0·00159
4	1·585	0·6310	2·512	0·3981	29	28·18	0·03548	794·3	0·00126
5	1·778	0·5623	3·162	0·3162	30	31·62	0·03162	1000·0	0·00100
6	1·995	0·5012	3·981	0·2512	31	35·48	0·02818	—	—
7	2·239	0·4467	5·012	0·1995	32	39·81	0·02512	—	—
8	2·512	0·3981	6·310	0·1585	33	44·67	0·02239	—	—
9	2·818	0·3548	7·943	0·1259	34	50·12	0·01995	—	—
10	3·162	0·3162	10·000	0·1000	35	56·23	0·01778	—	—
11	3·548	0·2818	12·59	0·07943	36	63·10	0·01585	—	—
12	3·981	0·2512	15·85	0·06310	37	70·80	0·01412	—	—
13	4·467	0·2239	19·95	0·05012	38	79·43	0·01259	—	—
14	5·012	0·1995	25·12	0·03981	39	89·13	0·01122	—	—
15	5·623	0·1778	31·62	0·03162	40	100·00	0·01000	—	—
16	6·310	0·1585	39·81	0·02512	41	112·20	0·00891	—	—
17	7·080	0·1412	50·12	0·01995	42	125·90	0·00794	—	—
18	7·943	0·1259	63·10	0·01585	43	141·30	0·00708	—	—
19	8·913	0·1122	79·43	0·01259	44	158·50	0·00631	—	—
20	10·000	0·1000	100·00	0·01000	45	177·80	0·00562	—	—
21	11·22	0·0891	125·9	0·00794	46	199·50	0·00501	—	—
22	12·59	0·0794	158·5	0·00631	47	223·90	0·00447	—	—
23	14·13	0·0708	199·5	0·00501	48	251·20	0·00398	—	—
24	15·85	0·0631	251·2	0·00398	49	281·80	0·00355	—	—
25	17·78	0·0562	316·2	0·00316	50	316·20	0·00316	—	—

if any change has been made at all. Table 2 shows that 3 db. corresponds to double (or half) the power, hence it is clear that 50 per cent. more or less power makes a negligible difference to the volume of sound when judged aurally.

Frequency Range:—Fig. 2 indicates the frequency ranges covered by various sources of sound. Musical instruments often emit noises that are not strictly a part of their true tone, such as the puffing sound of the flute and the scrape of the violin bow. These extraneous noises are usually high pitched and extend the upper limit of the spectrum as indicated by the dotted sections of the lines in the diagram. The ear is not very sensitive at the extreme upper and lower limits of frequency, which can often be cut out altogether without any serious effect. The crosses on the diagram show the upper and lower cut-off points that are just detectable by the average person.

For example, the piano has a frequency range from 70 to 6,500 cycles, but the ear would notice nothing amiss if only frequencies of from 100 to 5,500 were reproduced. Fig. 3 gives the theoretical frequencies of the notes on the piano keyboard. The extreme bass notes, however, are so strong in harmonics that the fundamental is actually inaudible; this accounts for the relatively high cut-off indicated in Fig. 2. Although the useful frequency range of a full orchestra extends from 30 to 15,000 cycles, only 8 people out of 10 can detect the difference when the range is restricted to from 80 to 8,000 cycles.

The speech spectrum extends from 120 to 10,000 cycles, but the range upon which one depends for the understanding of articulation is almost entirely above 500 cycles. A bass cut-off at 500 cycles gives thoroughly understandable speech, but the result is, of course, very unnatural.

Intensity and Tone Balance:—Imagine an equipment to be adjusted to reproduce a variable frequency test record at say, 90 db. above the threshold of hearing (referred to the 1,000 cycle note), and to be so perfect that all the pure tones from 30 to 15,000 cycles sound equally loud. Turn down the volume control until the 1,000 cycle note is reduced by 30 db., making it now 60 db. above the threshold. It might reasonably be expected that, on replaying the

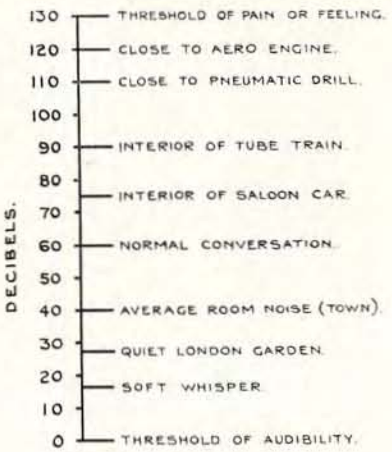


Fig. 1. Showing the relative levels expressed in decibels of various characteristic noises.

complete record, all the frequencies would still sound equally loud but would be 30 db. below the original rendering. However, the ear places quite a different interpretation upon the procedure. The band between 500 and 2,000 cycles would still sound constant in volume but above 2,000 cycles the volume would seem to fall slightly while below 500 cycles the ear would estimate the following drastic reductions: —10 db. at 200 cycles; —25 db. at 100 cycles; —45 db. at 50 cycles and —60 db. at 30 cycles. Thus the 30 cycle note would be down to the threshold of hearing and lower frequencies would be inaudible. This unexpected effect is due to no fault in our imaginary equipment but to the complicated variations in the sensitivity of the human ear dependent upon frequency and intensity.

The foregoing is perhaps a little confusing at the first reading, but an example will show how a knowledge of the effect mentioned above can be applied with success to everyday problems.

"Voicing" P.A. Equipment:—Wireless quality enthusiasts will know to their sorrow that a "straight line" amplifier gives splendid results when turned to full volume, but, when subdued to suit the listening conditions in a small room, the orchestra at once recedes into the distance behind the loud speaker. This is because the ordinary volume control reduces all frequencies in the same proportion while the ear interprets such a process as a greater reduction in the treble and bass than in the intermediate band from 500 to 2,000 cycles. The correction is to boost the extreme frequencies. The orchestra will seem to come forward into the room, producing that quiet but intimate effect so essential for the complete enjoyment of listening. A circuit capable of producing this result is fully described in "Partridge Amplifier Circuits."

P.A. work often calls for the reverse process, namely that of reproducing the voice at a level far above any utterance of human origin. The usual experience is precisely what one would expect from the foregoing examples. The low

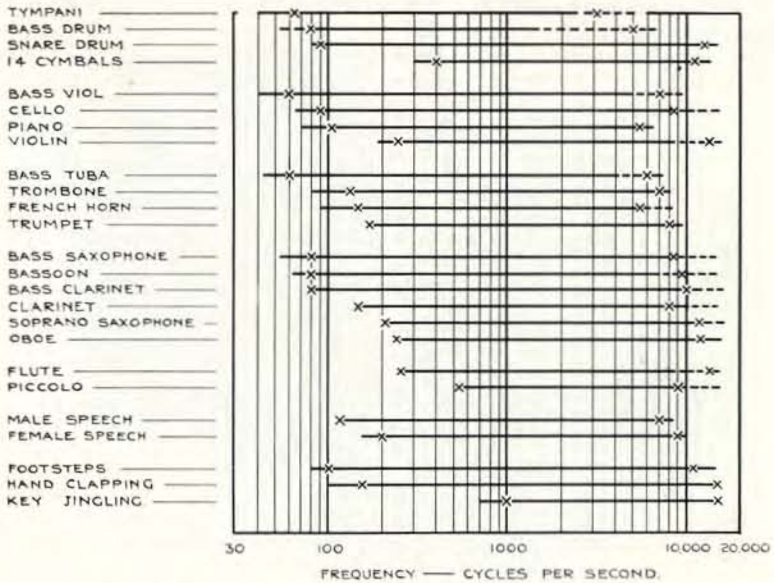


Fig. 2. Audible frequency range of various sources of sound. The crosses mark the cut-off points that are just detectable by the average person.

chest tones become overpowering, the speech unnatural and not very intelligible. To eliminate these defects, the bass and, to a much lesser degree, the treble must be attenuated.

Summarising, P.A. apparatus being generally used to reproduce sounds at or above their natural intensities, requires adjustable controls for attenuating the treble and bass. Radio or gramophone amplifiers for home use which usually function at or below the volume of the original source of sound need tone correcting circuits for boosting treble and bass. These conclusions do not take into account the effects of needle scratch, side-band twitter, recording characteristics, room acoustics or resonances, each of which must be treated as a separate problem

POWER AMPLIFIERS

Section (a) THE OUTPUT STAGE

The time honoured push-pull output stage (Class A) remains unrivalled where the highest possible quality is required and where cost and weight are not important considerations. However, there are many instances where economy has to be taken into account side by side with quality, and a variety of high efficiency circuits has been devised, especially since the advent of the American 6L6 beam tube and its British counterparts (KT66, etc.).

High Efficiency Circuits:—Class B is the best known of these circuits. Unfortunately, ignorance on the part of designers quickly led the industry to think that this system was incapable of even tolerable quality. This was an erroneous idea and in the issue of the "Wireless World," dated March 22nd, 1935, Mr. N. Partridge, B.Sc., A.M.I.E.E., set down the fundamental principles of good design in an article entitled "Class B Transformers."

With the introduction of Class A—B or Low-Loading, history has repeated itself, and bad quality due to the incorrect design of the transformers employed is often wrongly attributed to the circuit. As long ago as 1933 Mr. Partridge designed the iron-cored components for a

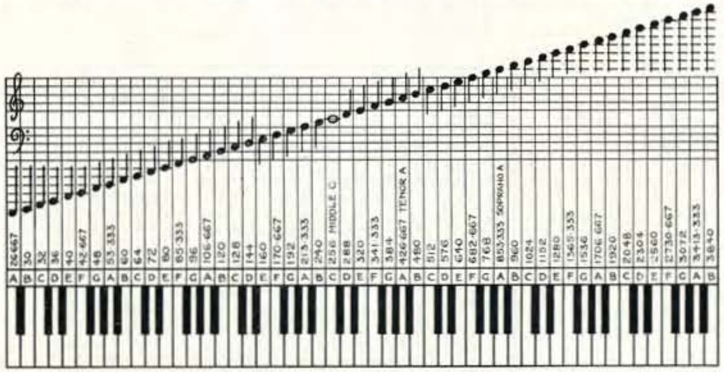


Fig. 3. This diagram, showing the frequencies of the notes on the piano, will be found very useful for the approximate calibration of oscillators, rough determination of resonant frequencies, etc.

Class A—B amplifier with an output of 120 watts at the request of what was then the largest relay company in the country. So successful was the result that 90 of these amplifiers were built, all equipped with Partridge transformers throughout. The quality attained even in these early days may be judged from the fact that the above-mentioned amplifiers are still in service and conform to the new P.O. regulations in spite of the severe standards stipulated for response and harmonic distortion.

For success with the modern circuits two things are necessary:—(1) a good circuit design, and (2) the correct iron-cored components for that particular circuit. The transformer design has become the central feature and this applies not only to the audio transformers, but to the mains equipment, as will be explained in a later section.

Method of Operation:—Fig. 4a shows diagrammatically the operation of a normal push-pull output stage (Class A). The characteristic curves (dynamic) for the two valves are shown to the left of the diagram one above the other.

A sine wave voltage applied to the grids will produce the current curves shown to the right, V1 being displaced by half a cycle relatively to V2, since the grid of V2 receives a negative impulse while V1 is receiving a positive one. These currents are combined in the output transformer where V1 is inverted relative to V2, so that the final effect is as shown by the curve marked V1 plus V2. The important points to note are (1) the individual valves operate exactly as they would if each were working in a straight single valve output stage; and (2) the anode current taken by the valves remains constant from no load up to the full power output the stage is capable of delivering. This latter fact makes automatic or self-bias a simple and very satisfactory proposition.

Fig. 4b illustrates a Class B stage in a similar manner. In this case the valves are biased back until practically no anode current flows. The effect of applying a signal is to produce half-cycle impulses from each valve alternately. When these are combined by the output transformer the result is similar to

that produced in case (a) with one big exception. The anode current drawn by the valves varies widely with the load on the amplifier. When the amplifier is standing idle the anode current is very low because the valves are over biased, but when a signal is applied the anode current increases in proportion to the magnitude of the signal. This variation of anode current puts automatic or self-bias out of the question and fixed bias, in the form of a battery or separate mains unit, has to be used.

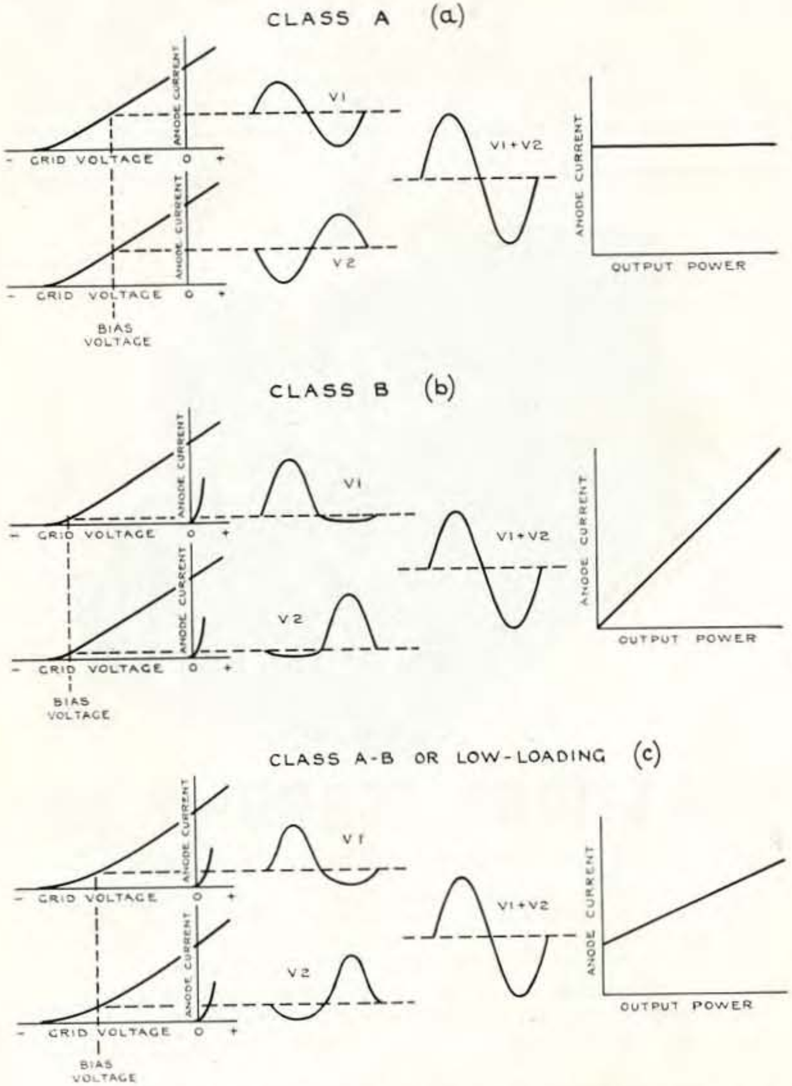


Fig. 4. Illustrating the operation of push-pull output valves when working in Class A, Class B and Class A—B (low loading). The transformer design and grid-bias are the factors governing the manner in which the valves function.

Grid Current:—If the grid swing is not allowed to exceed the bias voltage, i.e., the grids do not go positive, we have the once popular Q.P.P. circuit, but by taking special precautions in the design of the penultimate or driver stage it is possible to drive the grids positive without introducing distortion and a considerably greater power output can be obtained from the same valves. Thus by different circuit and transformer designs Class B can be operated with or without grid current, but never with automatic or self-bias.

Fig. 4c shows how Class A—B or low-loading operates. This arrangement is of more recent origin but has proved itself to be highly satisfactory and is capable of excellent quality at low initial and running costs. The valves are biased to a point intermediate between that required for Class A and Class B. When a small signal is applied to the stage its operation is similar to Class A as indicated in Fig. 4a. But when the signal becomes large the valves pass the current wave forms illustrated in Fig. 4c which, when combined in the output transformer, again produce the desired signal wave form. The anode currents in this case vary with the signal but not to the same degree as in Class B. The exact variation from no load to full load depends upon the valves employed and the circuit design, and may or may not permit automatic or self-bias (see Table 3).

Transformer Design:—As in the case of Class B the grids of the valves in a Class A—B or low-loading stage may be driven positive by using a properly designed driver stage and greater output power can be obtained from the pair of valves. Thus a Class A—B audio power amplifier may be designed to operate with or without running into grid current and each of these arrangements may be designed to function with self- or fixed bias, but each of these four possibilities will require a different design for the transformers employed.

At this juncture it may be mentioned that Class A—B operated without grid current (fixed or self-bias) is, in the opinion of the author, the most satisfactory scheme. This opinion is supported by the G.E.C., who recommend the use of four KT66 valves in Class A—B without grid current rather than two KT66 valves in positive drive giving the same output. The technique of positive drive is very susceptible to error and the cost of an adequate driver stage combined with that of the larger power unit counterbalances the saving effected by obtaining the higher output from two instead of from four output valves.

American Circuits:—The writer has been privileged to assist many engineers who have run into difficulties with Class A—B, especially in the use of the American 6L6 tube. In every case the trouble was due to the user not appreciating the vital importance of the transformer design as applied to the different types of circuit mentioned in the previous paragraph.

The American journals are particularly prone to mislead British readers. The 6L6 is depicted in a variety of amplifiers delivering anything from 15 to 60 watts output. These circuits look very similar and the transformers shown schematically appear identical and in every way normal components—this is the cause of disaster: Class A—B transformers are quite abnormal! The temptation to try out a high efficiency circuit with transformers that happen to be on hand must be resisted. No idea of the capabilities of such circuits can be obtained in this way.

Owing to the limited knowledge of transformer manufacturers concerning advanced amplifier technique, there is only a limited choice of really satisfactory components available in this country. Messrs. G.E.C., Mullards, Tungsram, etc., all recommend Partridge Transformers for their Class A—B constructional amplifiers.

A selection of modern high efficiency circuits, together with recommended components and constructional details, is published in "Partridge Amplifier Circuits," obtainable from N. Partridge, B.Sc., A.M.I.E.E., King's Buildings, Dean Stanley Street, London, S.W.1, price 2/- nett.

TABLE III.

TYPE.		VOLTS.				CURRENT M.A.				Optimum Load.	Power Output.
		Anode.	Scr'n.	Grid Bias.		Anode.		Screen.			
Make.	No.			Automatic	Fixed	No Load.	Full Load.	No Load.	Full Load.	Ohms.	Watts.
Class A (single valve):—											
Osram ..	PX25A	400	—	100	—	—	62·5	—	—	4,500	8·4
,, ..	DA30	500	—	134	—	—	60	—	—	4,000	10
,, ..	DA100	1,000	—	146	—	—	100	—	—	6,700	30
,, ..	KT66	250	250	16	—	—	80	—	6	2,200	8
,, ..	KT31	200	180	4·4	—	—	40	—	10·6	5,500	2·5
Mullard ..	Pen.428	250	250	12	—	—	72	—	?	3,200	8
,, ..	DO26	400	—	92	—	—	63	—	—	4,000	7
Tungsram	P60/500	600	—	110	—	—	130	—	—	2,600	15
American	6L6	300	200	12	—	51	54·5	3	4·5	4,500	11
Class B with Grid Current (per pair of valves):—											
American	46	400	—	—	0	12	120	—	—	5,800	20
,, ..	49	180	—	—	0	4	30	—	—	12,000	3·5
Class A—B, no Grid Current (per pair of valves):—											
Osram ..	PX25A	440/400	—	—	117	114	200	—	—	2,800	32
,, ..	DA30	500/480	—	—	145	100	220	—	—	3,400	45
,, ..	DA100	1,000	—	146	—	200	212	—	—	8,000	90
,, ..	KT66	250	250	18	—	120	150	7	17	4,000	17
,, ..	KT66	400	300	—	27	100	165	4	19	5,700	38
,, ..	KT31	200	180	6	—	45	57	11	19	8,000	6
Mullard ..	Pen.428	375	275	17·5	—	96	124	10	18	6,500	28
,, ..	DO26	440/400	—	—	115	110	200	—	—	2,800	32
Tungsram	P60/500	900	—	—	250	60	180	—	—	12,000	70
American	6L6	400	300	23·5	—	112	128	7	16	6,600	32
Class A—B, with Grid Current (per pair of valves):—											
Osram ..	DA100	1100/1000	—	—	150	200	330	—	—	8,000	200
American	6L6	400	300	—	25	102	230	6	20	3,800	60

Modern high efficiency valves require a circuit technique quite different from that employed for ordinary push-pull. Complete amplifier designs utilising many of the above valves are published in "Partridge Amplifier Circuits", price 2/- nett.

Section (b) THE PARTRIDGE CONTROL CIRCUIT

The most recent advance in high efficiency circuits relates to the use of beam tubes and high power pentodes. Until the invention of the Partridge Control Circuit it was not possible to obtain in practice the high efficiencies claimed by the manufacturers of these valves, owing to the difficulty of maintaining the screen voltage constant under working conditions.

Table 3 shows that the Pen 428, KT66, 6L6, etc., all require a screen voltage approximately 100v. below that of the anode in order to obtain maximum efficiency. This drop of voltage cannot be obtained by a simple series resistance because the screen current varies with load and the voltage drop would consequently vary in the same proportion. A potentiometer or bleeder resistance can be used but, to keep the screen voltage constant within the close limits required by the valve manufacturers, the power wasted in the potentiometer has to be so great as to nullify the high efficiency attained in the valve itself.

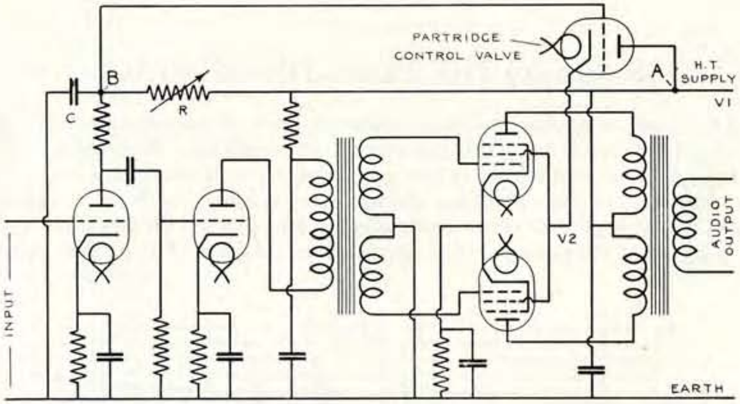


Fig. 5. The Partridge Control Circuit. Invented and provisionally patented by N. Partridge, B.Sc., A.M.I.E.E., patent rights purchased and controlled by The Mullard Radio Valve Co., Ltd.

The Partridge Control Circuit, of which this is the first published description, obviates all waste of power in the screen supply and keeps the screen voltage more nearly constant than has been hitherto possible. This important addition to the technique of amplifier design is due to the work of Mr. N. Partridge, B.Sc., A.M.I.E.E., who invented and provisionally patented the device illustrated in Fig. 5. The preliminary tests with the Pen 428 proved so successful that Messrs. Mullard Radio Valve Co., Ltd., at once negotiated for, and purchased, the patent rights which are now owned and controlled by that company.

The operation of the circuit is briefly as follows:—The screens are supplied with current through an ordinary triode valve known as the Partridge Control Valve. The anode of this valve is connected to the main source of H.T. (point A) and the cathode to the screens which are to be supplied with varying current at a constant voltage (V2). The grid of the valve is maintained at the same potential (V2) as it is desired to keep the said screens. This can be done very conveniently by connecting the grid to a point (B) in the H.T. supply to the earlier stages of the amplifier that can be adjusted to the required voltage (V2) by means of a variable decoupling resistance (R). The change of voltage of the screens as the current varies will depend upon the mutual conductance of the Control Valve. If this is say 4 m.a. per volt, a change of 8 m.a. in the screen current will result in a drop of only 2 volts, which is negligible, being only about 0·5 per cent. of the total screen voltage. A further advantage is that the Partridge Control Valve also decouples and smooths the screen supply to an extent dependent upon the amplification factor of the valve.

A complete amplifier design incorporating the above scheme is published among others in "Partridge Amplifier Circuits," price 2/- nett. This circuit, which has been christened the "Partridge Economy 28," employs the Pen 428 valves and gives an undistorted output of 28 watts, while the cost, size and weight are similar to those of the usual 12 watt amplifier. Many attractive features such as tone control, mixing, etc., are included and there is no doubt that the "Partridge Economy 28" will become one of the most popular circuits for general P.A. work. The experimental amplifier is illustrated on page 9.

Section (c) THE PENULTIMATE STAGE

The valve preceding the output stage is often responsible for a large percentage of the total distortion present in an amplifier. Resistance-capacity coupling, although excellent in the early stages, fails when used to feed the grids of modern power valves for the following reasons:—(1) The first trace of grid current charges the coupling condenser and blocks the amplifier, causing very prominent distortion. (2) Large power valves and negative feed-back

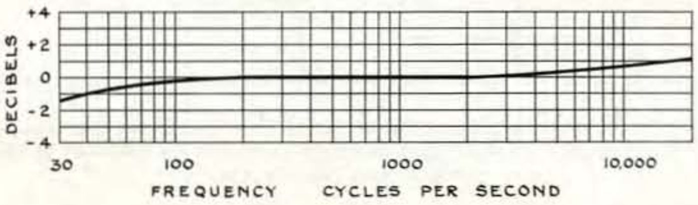


Fig. 6. Response curve of the Partridge Intervalve Transformer Type IV60.

circuits often require so large a grid swing that the penultimate stage may be overloaded before the full power is developed from the output stage. (3) The valve manufacturers stipulate that a low resistance grid circuit shall be provided in the case of certain output valves; this is difficult of attainment with resistance-capacity coupling. (4) A push-pull output stage needs a push-pull penultimate stage to drive it, and, even supposing the phase-splitting circuit to function perfectly, a large phase shift can occur by the time the signal reaches the grids of the output pair, especially at the higher frequencies.

Modern Practice:—Good transformer coupling is free from all of the foregoing objections, and for this reason is now considered better practice than the use of resistance-capacity coupling. This applies to high fidelity work as well

as to high efficiency circuits, but only between the penultimate and output stages. In the earlier stages resistance-capacity coupling retains its superiority for other reasons.

It remains to consider what constitutes a good intervalve transformer. Great changes have taken place in recent times which make the requirements more stringent, and transformers that only a short while ago were considered to be in the front rank have been superseded and remain but landmarks in the history of progress.

At one time the transformer overall frequency response curve was accepted as the criterion, but investigation has shown that a push-pull transformer may have a really good overall response and yet the two halves of the secondary may be badly out of balance at the higher frequencies. This is due to the leakage inductance and effective capacity being different for the two half secondaries (resistance is not important), thus giving a different resonant frequency to each half. Constructional designs have appeared from time to time in the popular press, in which balance is claimed by virtue of the use of two identical bobbins, each carefully sectionalized. This is good in theory but not in practice, because the windings cannot be adequately interleaved and insulated to withstand high surge voltages. Partridge Intervalve Transformers adopt a different principle which completely removes the resonant frequency from the audible range and combines a sound construction with accurate balance from 30 to 15,000 cycles. Fine gauge wire, pile wound, is unreliable because the high grid swings required to operate modern circuits result in short circuited turns developing after a period of use. The Partridge transformers to which reference has been made above are wound with relatively heavy gauge wire and are fully paper interleaved with the same care as is given to mains equipment. These transformers will stand indefinitely a swing of 500v. R.M.S. without fear of damage and consequently breakdown in service is unknown.

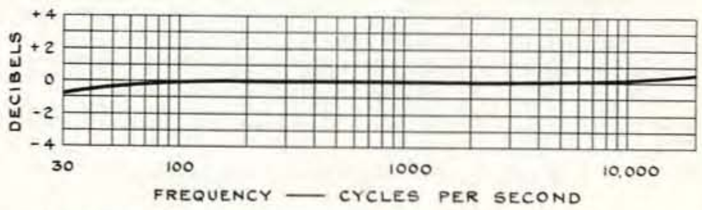


Fig. 7. Response curve of the Partridge Intervalve Transformer Type IV240.

A good transformer should not require to be filter fed, except in special circumstances. The Partridge IV60, IV120, and IV240 are all designed to carry the full anode current of the preceding valve and filter feeding will not bring about any improvement in the quality of reproduction.

Type IV60:—The Partridge IV60 Intervalve Transformer is designed to be connected directly in the plate circuit of a valve having an A.C. resistance of approximately 10,000 ohms, and passing up to 8 m.a., such as the MH41, MH4, MHL4, AC2HL, AC.HL, 354V, 244V, etc. The secondary is wound in two separate halves for push-pull working and the peak grid swing (grid bias) required by each of the output valves should not exceed 40v. Suitable output valves are the PX4, PX25, AC.P1, PP3/250, PP5/400, DO24, etc.

The response curve is given in Fig. 6. The slight rise around 10,000 cycles is useful in preserving clarity and sharpness of reproduction and partially compensates for the inevitable losses in other sections of the equipment. The loss of 1·5 db. at 30 cycles looks worse on paper than it sounds, being actually inaudible. It was found that with valves of 10,000 ohms A.C. resistance the loss of bass could not be reduced without introducing out of balance between the two halves of the secondary at the higher frequencies.

Type IV240:—This model was designed to feed the larger power valves in push-pull such as the PX25a, DO26, DO25, MZ05—60, MZ1—75, etc., which require a peak grid swing (bias voltage) of up to 120 volts. The preceding valve must have an A.C. resistance of about 3000 ohms, and may pass up to 25 m.a. plate current directly through the transformer primary without fear of saturation. Suitable valves are the ML4, AC.P, 104V, etc. A very important point to note is that each half of the secondary must be loaded with 75,000 ohms. The frequency response is shown in Fig. 7.

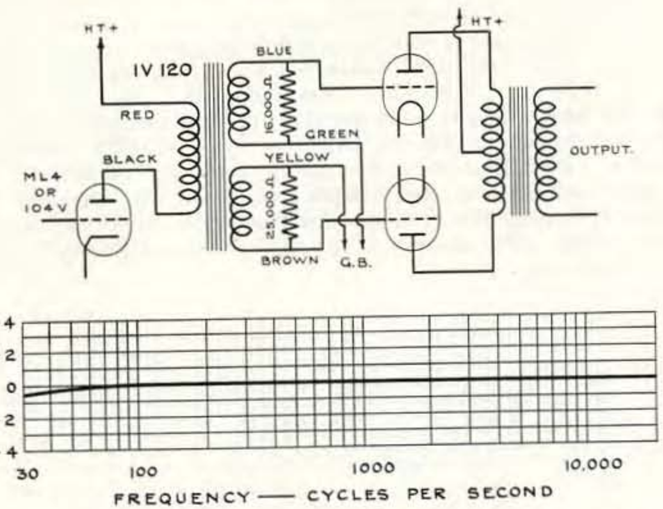


Fig. 8. Showing the circuit arrangement and response curve of the Partridge Intervalve Transformer Type IV120. This is probably the most perfect coupling obtainable.

High Fidelity, Class A:—The Partridge IV120 is widely used in recording and film studios, for which purpose it was originally developed, and is probably the most perfect intervalve coupling obtainable. The response is given in Fig. 8, together with the circuit diagram. The preceding valve must be of the ML4 or 104V class (as for the IV240), while the output valves should each require a grid swing (bias voltage) not exceeding 50v. It will be noted from the circuit diagram that the loading resistances are unequal, one being 16,000 ohms and the other 25,000 ohms. The object of this is to correct a very slight out of balance between the two half secondaries occurring at 12,000 cycles upwards. This out of balance is extremely small and its correction is a refinement rather than a necessity.

Class B and Class A—B with Grid Current:—Driver transformers for Class B and for Class A—B circuits in which the valves are driven into grid current are entirely different in theory and design from the Class A transformers described above. The same applies to cathode connected transformers used in certain negative feed-back circuits for reducing driver distortion. For satisfactory results a properly designed transformer must be used for every valve combination, and it is not possible to list a standard type. Specially designed Partridge Transformers can be wound at short notice for any circuit at prices comparable with those of the standard types.

Class A—B without Grid Current:—This is deservedly the most popular of the high efficiency circuits, and good examples of it are to be found in the Partridge 30w. Amplifier, using PX25a's, and in the Partridge Economy 28, using Pen.428's. Both circuits are described in "Partridge Amplifier Circuits," price 2/-. The audio transformers, however, are very critical and normal push-pull components will not give satisfactory results. The generation of parasitic oscillations on the falling half of the wave, which is closely linked with resonance and balance already discussed, is the major difficulty encountered. A really good Class A—B intervalve transformer may be employed in a high fidelity Class A circuit with confidence, but a good Class A transformer will not necessarily function in a Class A—B circuit. In other words, if distortion is to be avoided in Class A—B circuits, the intervalve and output transformers must be superior components to those needed for Class A.

General Operation:—A valve having a transformer in its plate circuit necessarily operates with an inductive load at the lower frequencies. From this it follows that the dynamic load line is an ellipse. To minimize harmonic distortion the valve should be given its maximum anode voltage and slightly under biased, so that the anode current is in excess of the figure specified by the manufacturer for average conditions. There will be no danger of damage to the valve providing the anode dissipation does not exceed the manufacturer's rating.

Nickel Alloy Components:—The midget parallel-fed intervalve transformers usually associated with nickel-iron are not recommended for use in amplifiers. However, there are a number of special cases (crystal microphone, photo-cell, etc.) where the proper employment of high permeability alloys will produce results unobtainable by any other means. The application of these alloys is a specialised study and readers requiring advice or quotations are advised to write to Mr. G. A. V. Sowter, B.Sc., A.M.I.E.E., who deals exclusively with this class of work (see page 36).

Section (d) MAINS EQUIPMENT

The growing popularity of high efficiency output stages has set new problems to be solved in the design of H.T. supply equipment. Owing to the variation of anode current with load, the rectifier circuits used for Class A amplifiers will not function satisfactorily with Class B or Class A—B units. The current variations to be met in practice are indicated in Table 3 (page 12).

Typical Characteristics:—In Fig. 9 are shown the characteristic curves of the American Type 83V and Type 5Z3 rectifiers when used in the circuits of Fig. 10a and b. The normal arrangement adopted for Class A circuits is that of Fig. 10a, in which the reservoir condenser (C1) is 4 m.f.; the appropriate curves can be picked out in Fig. 9.

Table 3 shows that the Osram PX25a's in low-loading (Class A—B) draw 114 m.a. at no load. If the 5Z3 rectifier is used with a 4 m.f. reservoir condenser and the H.T. voltage adjusted to its correct value (420v.) while the amplifier is idle, it can be seen from Fig. 9 that the voltage will drop to 360v. when the valves are fully loaded and drawing 200 m.a. This is obviously unsatisfactory, and will, in fact, prevent the full output of 32 watts being attained.

One method of improving the voltage regulation is to increase the reservoir condenser, and, in the case of the 83V, curves are given for 8 m.f. These are appreciably more level and are satisfactory for those Class A—B circuits in which the current variation is not considerable. For example, the Pen. 428's take 96 m.a. at 375v., on no load. If the 83V is used in conjunction with an 8 m.f. reservoir condenser, the voltage at the full load current of 124 m.a. will be 360v. The drop being only 4 per cent., may be taken as satisfactory.

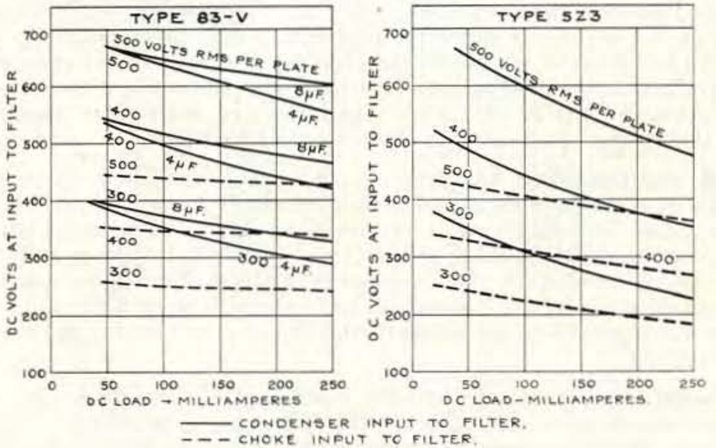


Fig. 9 Characteristic curves of the American 83V and 5Z3 rectifiers when operated in the circuits of Fig. 10 (a) (full lines) and Fig. 10 (b) (dotted lines).

Reservoir Condensers:—The choice of a suitable reservoir condenser is important, and generally speaking electrolytic condensers are not suitable. There are two reasons:—(1) The highest working voltage generally obtainable is of the order of 500v. The peak voltage to which the reservoir condenser is charged during each cycle is 1·4 times the transformer R.M.S. voltage. Hence the highest transformer voltage that can be employed with a 500v. electrolytic reservoir condenser is 350—0—350v. (500 divided by 1·4). (2) Electrolytic condensers cannot pass more than a very limited A.C. ripple current without rapid deterioration. In the case of most 500v. working types the maximum ripple is limited to 100 m.a. Now the ripple current passed by a reservoir condenser is approximately equal to the D.C. current taken by the amplifier, hence it follows that if an H.T. unit is required to pass more than 100 m.a. rectified D.C., an electrolytic condenser cannot be used as the reservoir. The author has observed that this important technical point has been ignored in several circuits emanating from sources that one would have expected to be better informed.

An electrolytic condenser of the 500v. working type can be used with safety as a reservoir only if the transformer voltage does not exceed 350-0-350v. and the total rectified current is under 100 m.a. If either of these figures is exceeded a paper condenser must be used. The preceding remarks apply only to the reservoir condenser because the ripple current in the condensers following the smoothing choke is negligible.

Choke Input:—Returning to the question of regulation, the circuit of Fig. 10b is the one most suited to wide current variations, as in the case of the PX25a, DA30, etc. The reservoir condenser is omitted, and the first element of the smoothing filter is the choke. This slight alteration completely changes the characteristics of the rectifier. The full theory was given in the issues of the "Wireless World," dated December 20th and 27th, 1935, in an article entitled "Choke Input Filters," by N. Partridge, B.Sc., A.M.I.E.E. This is too complicated to repeat here, and the following remarks will be confined to practical considerations.

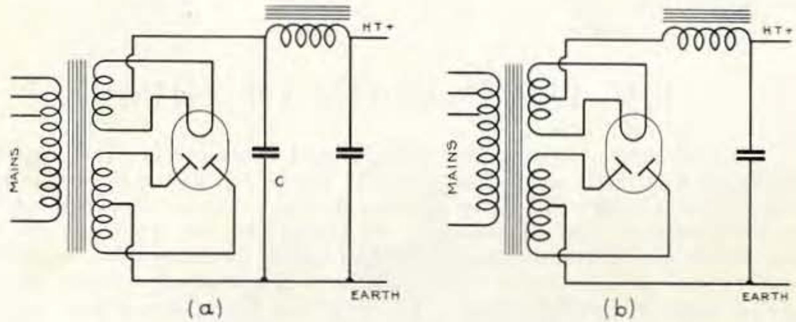


Fig. 10. (a) illustrates the usual condenser input to the smoothing filter, while (b) shows the choke input circuit that has to be used where good H.T. regulation is essential.

The relevant curves are shown in Fig. 9 for the two valves selected. It can be seen that with a fixed transformer voltage the rectified D.C. voltage is much lower with a choke than with a condenser input to the filter, but the regulation is vastly improved. The best results are obtained with mercury vapour rectifiers, but with this type of valve two points have to be watched:—(1) a thermal delay switch is essential, so that the H.T. is not switched on until the filament has been heated for a minute or so, and (2) high frequency oscillation is liable to occur, rendering the operation of the valves irregular.

Special Choke Design:—The choke forming the input to the smoothing filter, i.e., the "swinging choke" of Fig. 10b, has to be a very specially designed component. A high A.C. voltage is developed across its terminals and consequently the choke must be interleaved—the usual smoothing choke will break down after a period of service. Again, the inductance must vary inversely as the D.C. current, and the value of the inductance at various currents is critical and depends upon the H.T. voltage, among other factors. The correct design demands a specialised knowledge of the theory of the circuit, and any guesswork will lead to dissatisfaction. The design of Partridge Filter Input Chokes is soundly based upon scientific principles.

Another important consideration is the resistance of a swinging choke. Resistance causes a drop of voltage depending upon the current passing. Since the current in Class B and Class A—B circuits varies, so will the voltage dropped across the choke and a very low value of resistance is necessary for good regulation. This again is a matter for calculation, and is best left in the hands of a competent manufacturer who understands not only the winding of chokes but the theory underlying their operation and that of the circuits in which they are to be employed.

All mains equipment must be handled with great care, for misadventure may prove fatal. Particularly is this true since the advent of television. These high voltages have caused considerable trouble among transformer manufacturers, the difficulty being to produce a reliable component that will not flash over after a period of use. Unnecessary expense and disappointments can often be avoided by following the lead of experienced users—Messrs. Mullard, Messrs. T.C.C., and many other well known companies employ Partridge High Tension Transformers in their test and experimental equipment, the former company having a number of transformers working satisfactorily at no less than 20,000 volts.

THE ELIMINATION OF HUM

A background of hum is objectionable and unnecessary. Much can be done in the first instance by clean and tidy wiring, but in any eventuality a systematic investigation of a purely commonsense character should suffice to provide a remedy. Always assume at the outset that the trouble is due to some simple and obvious cause that only requires locating to be removed. Guard against the temptation to try a series of disjointed experiments in the hope of immediate enlightenment. To work to a preconceived plan as described below may seem laborious, but in the long run it is certain to produce quicker results than guesswork.

The general procedure is to examine the amplifier stage by stage, considering the possible causes of hum under the three headings of (1) Inadequate Smoothing, (2) Magnetic Induction, and (3) Electrostatic Induction.

Output Stage:—Take the circuit of Fig. 11 as an example. To isolate the output stage without removing valves or upsetting bias or H.T. voltages, short-circuit the primary of the intervalve transformer, i.e., the points A and B. Switch off the amplifier while doing this and make a good connection by means of a short length of insulated lead. Switch on again—if all trace of hum has vanished the trouble is not in the output stage; if some persists it must be traced and cured before proceeding to the earlier stages.

(1) Inadequate Smoothing:—With a push-pull output stage this is an unlikely possibility, since all ripple should cancel out. Check the anode currents of the two output valves, which should be approximately equal, and check the centre taps of the filament windings, which should be exact in the case of directly heated valves.

(2) Magnetic Induction:—The intervalve transformer having its primary short-circuited is incapable of picking up hum from the mains transformer, hence the only object of suspicion is the output transformer. Trouble in this direction is rare, but a check can be made by unscrewing the component and turning it on its side. The intensity of induced hum will vary as the direction of the axis of the winding is changed.

(3) Electrostatic Induction:—This is a common form of interference in the first stage of an amplifier, but will not be present in the output stage unless a very high resistance or open circuit is present in one or both of the grid leads. See that the core of the intervalve transformer is effectively earthed, and check continuity of the secondary winding. (*Note*:—The resistances of the two half secondaries may not be equal; this is of no importance and does not necessarily indicate a faulty component.) Short circuit R7, if this reduces the hum it is probable that too high a resistance is being employed; 30,000 ohms is sufficient.

Penultimate Stage:—Remove the short-circuit across A—B and apply it to C—D. Any additional hum arising after this operation must have its origin in the penultimate stage.

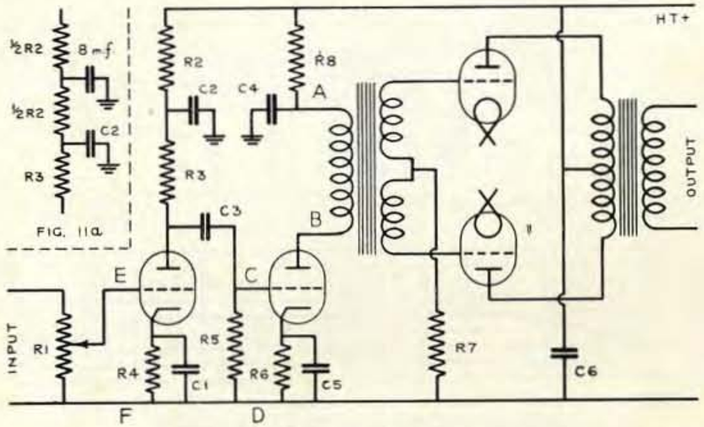


Fig. 11. A typical amplifier circuit used in the text to illustrate how to locate and remove hum.

(1) Inadequate Smoothing:—This is most easily checked by temporarily connecting a spare 8 m.f. condenser in parallel with C4 and noting if the hum is appreciably reduced. If a reliable circuit design has been followed any failure in the smoothing must be due to a faulty component or connection—most probably the latter. Likely errors are:—C4 open circuited, decoupling resistance of too low a value, smoothing choke short-circuited or omitted, etc.

(2) Magnetic Induction:—The intervalve transformer is the most likely offender in this respect. It should be as far from the mains transformer as possible and at right angles to it—preferably screened by some intervening iron cored component. Unscrew the transformer and turn it in various directions, noting if the hum intensity changes. If it does, magnetic induction is present, and a new position must be found by experiment.

(3) Electrostatic Induction:—This is not a probable source of interference at this point.

First Stage:—Transfer the short circuit from C—D to E—F, making the connection from the grid of V1 to the chassis close against the valve holder, by means of a short length of wire. Proceeding as before:—

(1) Inadequate Smoothing:—Connect a spare 8 m.f. condenser in parallel with C2; a noticeable reduction of hum will indicate A.C. ripple in the H.T. supply. If a good circuit design has been followed look for faulty connections

or components, but if there is reason to suspect the adequacy of the smoothing arrangements an additional filter may be provided. In the circuit of Fig. 11, R2 and C2 form the decoupling and smoothing filter. To increase its efficiency without upsetting the voltage applied to the anode of V1 the scheme of Fig. 11(a) may be employed. R2 is replaced by two resistances in series, each being one half of the value of R2. A condenser of 8 m.f. is connected from the mid-point to earth. This arrangement is considerably more effective than simply adding 8 m.f. in parallel with C2, although the total resistance and capacity is the same in each case.

(2) Magnetic Induction:—In the absence of any iron-cored coupling components this form of induction is improbable.

(3) Electrostatic Induction:—The grid of V1 being directly earthed, electrostatic pick-up is also improbable.

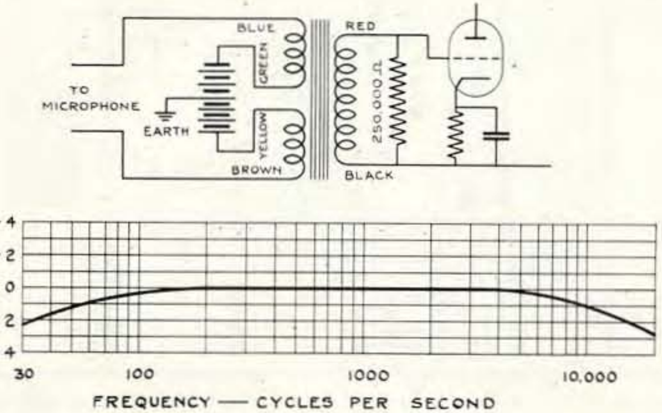


Fig. 12. The circuit diagram and response curve of the Partridge Microphone Transformers Types M250/350 and M400/600. Note that the primary is split into two equal sections so that the line may be balanced with respect to earth.

Input Circuits:—All three stages have now been cleared of hum, and yet when the short-circuit is removed from E—F it is very probable that pronounced hum will immediately become audible. This is due almost entirely to electrostatic pick-up by the grid leads, and will be most evident when the volume control is turned to maximum. If the first valve is not metallized, a screening can should be fitted over it. See that the metal case (if any) of R1 is earthed. Keep all leads as short as possible, and run them close to the chassis. Never rely upon the chassis as an earth return, but connect a proper earth wire from point to point. Finally, make a rough screen of tin or aluminium to shield the under-chassis grid wiring of V1 and the input circuit from the remainder of the wiring and from the bench or table upon which the amplifier stands. This screen does not have to be elaborate, simply a strip of sheet metal roughly bent to shape and fixed in position, care being taken that it is not likely to make contact with any of the wiring or components.

In the case of high gain amplifiers, interference may be caused by the L.T. filament supply to the first valve. This can be minimized by discarding the centre tap provided on the mains transformer and connecting a potentiometer (or humdinger), so that the earthed point can be adjusted to suit the conditions. Further hints will be found under "Background Noise," on page 26.

An important feature of the Partridge Service is that should any special difficulty be encountered with an amplifier employing Partridge Transformers, expert technical advice is given free of all charge. Correspondence should be addressed for the attention of Mr. N. Partridge, B.Sc., A.M.I.E.E., and full details enclosed together with 3d. in stamps to cover the cost of reply.

INPUT CIRCUITS

A pick-up, microphone, sound-head or similar device must be employed to provide the initial audio voltage required to operate an amplifier. Of these the microphone is of the greatest general interest.

The author favours the carbon microphone for general work. Price is a governing factor. A really good carbon microphone is superior to a poor moving coil or ribbon, and a high price must be paid if any advantage is to be gained by the use of these latter types. A graded list of satisfactory microphones will be found in the appendix.

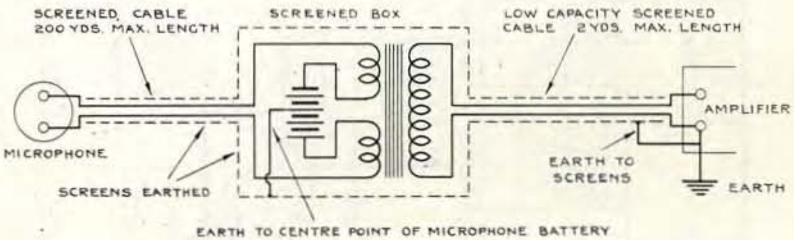


Fig. 13. The correct method of connecting and screening a microphone line.

Microphone Transformers:—A transformer must be used to step from the impedance of the microphone to that of the amplifier input. This component is in some respects similar to an intervalve transformer, but presents even greater problems of design and production. Small, cheap models cannot give a satisfactory performance and vitiate the good points of the following amplifier.

The early microphone transformers were abominable, it once being popularly believed that 5/- was quite enough to pay for so unimportant an item. This fact threw an amusing side-light on the history of the Partridge Microphone Transformer. Its first appearance was almost ignored, save for a few caustic observations on what was then considered to be its absurdly high price. After some time a new and very entertaining phase set in. A customer would approach the works, glance furtively around to ensure that no one else was about to enter and then slip quietly in. Once inside it became clear that his business was highly confidential and one would withdraw to a discreet distance from other customers and converse in low tones with repeated glances from left to right. The usual result of these obscure conferences was that the customer in exchange for a few coins received a securely tied, plain package which in truth contained a Partridge Microphone Transformer. The sensations of the customer were obviously akin to those of embarrassment one experiences when purchasing certain requisites in a strange chemist's shop. These pioneers of quality feared the scorn and derision that might be cast upon this seemingly idiotic extravagance. The 1936-37 season may be quoted as a sequel to the story, when Partridge Microphone Transformers had the largest sale of any one type, and additional winding plant had to be installed to handle the demand. This episode is typical of the growing mastery of quality over price and says much for the discernment and appreciation of the average user.

Improved Models:—Two entirely new models have recently been introduced. These are the Partridge M250/350 and M400/600; the former is for carbon microphones of from 250 to 350 ohms impedance, and the latter for 400 to 600 ohms impedance. Both will pass 50 m.a. through the primary winding without loss of inductance. Fig. 12 shows the method of connection and a typical response curve. A great improvement has been brought about by splitting the primary winding so that the battery and earth can be applied at the centre point. This balances the line with respect to earth and substantially reduces line pick-up. Transformers constructed in this manner can be supplied at short notice for any type of microphone.

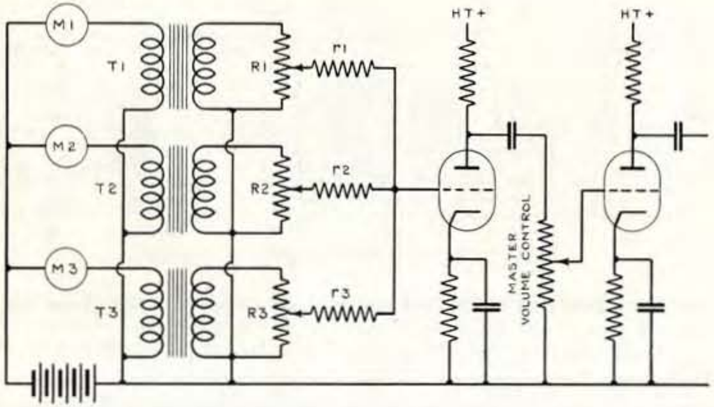


Fig. 14. Mixing three high sensitivity microphones. Note the master volume control, the use of which is explained in the text. R1, R2, R3, r1, r2, r3 are all 250,000 ohms.

Microphone transformers are very sensitive to stray magnetic and electrostatic fields and should not be mounted on an amplifier chassis or hum will be induced. The transformer, together with the microphone battery, should be housed in a metal lined box and kept a few feet away from the amplifier. The lead from the transformer secondary to the amplifier input must be kept short, say two yards maximum length, and should be of low capacity. If high capacity cable or a long length of cable be used in this part of the circuit the upper frequencies will be seriously attenuated.

Line Lengths:—The length of line that may be used from the microphone to the primary of the microphone transformer is limited principally by capacity. A length up to 100 yards is safe with a 500 ohm microphone and this length will vary inversely as the impedance so that it may be 200 yards with

a 250 ohm microphone and so on. In all cases care should be taken that the total resistance of the line does not exceed 20 per cent. of the microphone impedance; this point requires special care when using low impedance moving coil instruments.

All microphone lines must be screened and the screens should be earthed together with the transformer box and microphone stand. Fig. 13 shows the correct method of doing this. The screening should be carried as close to the amplifier and microphone terminals as possible and should pass right into the battery box.

Mixing:—There are several ways of mixing input channels; some are too crude to be satisfactory, while others are too scientifically exact to be economical. The method described here is essentially practical and, while avoiding all possibility of harmonic distortion, employs a minimum of apparatus.

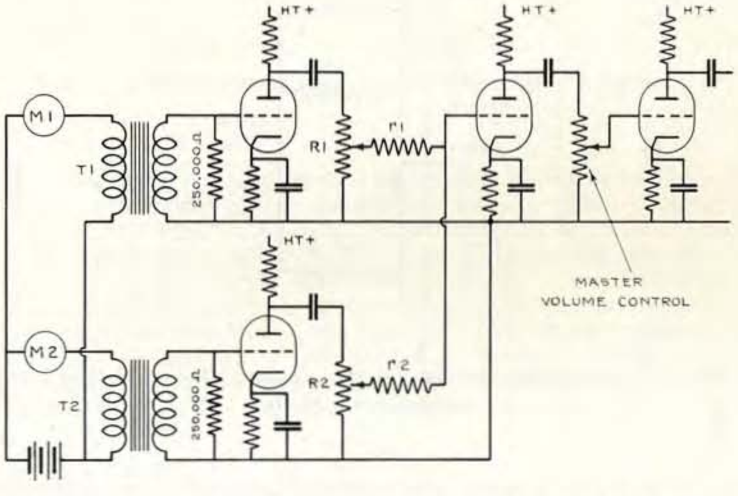


Fig. 15. This circuit is suitable for mixing low sensitivity microphones. Extra input channels can be added if desired. R1, R2, r1, r2 are all 250,000 ohms.

The scheme of Fig. 14 is suitable for two or three input circuits providing they are all fed from high sensitivity microphones (carbon) or pick-ups. All methods of mixing involve a loss of signal strength. If there are two input channels the voltage applied to the valve will be halved; if there are three it will be reduced to one-third and so on. It follows that the more input circuits there are the lower will be the signal reaching the grid of the first valve and hence valve noise (microphony, hiss, etc.) will become more evident. Another point to the note is that in the circuit of Fig. 14 there is always a high resistance between the grid of the first valve and earth, even when all controls are set at zero. The result is a relatively high hiss level at low volumes. This disadvantage can be overcome quite simply by having a master volume control after the first valve as illustrated in the diagram. By means of this control the overall gain can be kept to the minimum necessary, and during silent or idle periods all noise from the first valve can be cut out entirely.

High Gain Circuits:—With low sensitivity microphones (moving coil, crystal and ribbon) the preceding scheme is not satisfactory and it becomes necessary to employ a separate valve for each input and to mix after the first stage of amplification. This arrangement is illustrated in Fig. 15. The advantages are (1) there is always a relatively low resistance (transformer primary) between the grid of the first valve and earth, thus minimizing hiss, and (2) the maximum possible input voltage is applied to the grid, thus minimizing the effect of noise arising in the first valve. Here again it is a good plan to have a master control, in this case following the second stage.

A difficulty sometimes arises when it is desired to mix a sensitive pick-up with comparatively insensitive microphones. For example, suppose the pick-up delivers 2v. and the microphones only 0·05v., i.e., the pick-up is forty times

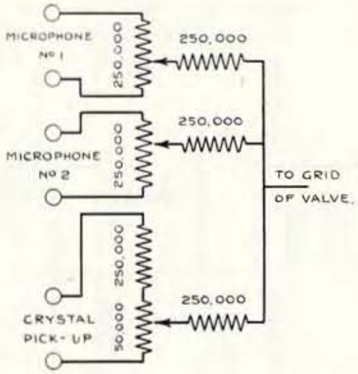


Fig. 16. A satisfactory circuit for mixing a sensitive pick-up with insensitive microphones (see text).

as sensitive as the microphones. To enable all the controls to be equally effective the device shown in Fig. 16 is convenient. The pick-up potentiometer is made about one-fortieth of the total input resistance and thus when the potentiometer is turned to maximum the signal will be approximately the same as that from the microphones when their controls are set to maximum.

Background Noise:—Valve noise is always a source of trouble in high gain amplifiers. The following hints will be found useful in this connection. (1) A separate filament winding for the first valve with a hum-dinger across it keeps hum to a minimum. (2) The first valve should be metallised or else screened. (3) Battery bias to the first valve avoids noise arising in bias resistor or electrolytic condenser and keeps the cathode effectively tied down to earth. (4) A wise choice of first valve makes an enormous difference. Apart from the special valves, the author favours the Mullard 164V or 904V for mains work or the Mullard PM2DX for battery use.

OUTPUT CIRCUITS

That a good frequency response is a fundamental requirement in an output transformer and that this is achieved by an adequate primary inductance coupled with a low leakage inductance are facts that have been altogether overstressed by the popular press. A level response is but one essential among many, and alone gives no indication as to the fidelity of reproduction that may be expected.

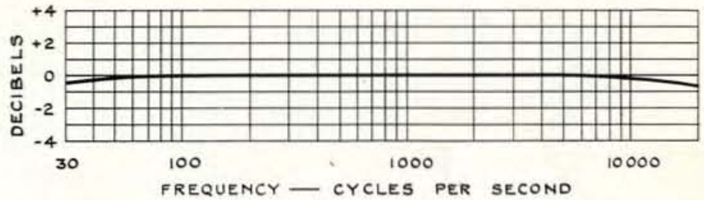


Fig. 17. A typical response curve of a Partridge Output Transformer.

High Fidelity:—Probably the best known high fidelity output transformers and the most widely used in professional circles, are those manufactured by Messrs. N. Partridge, whose audio components enjoy an extensive reputation on the Continent as well as in this country. The author has often been called upon to explain why the tonal quality obtained from a Partridge component is so definitely superior to that produced when using certain other well known transformers even though the response curves of the two instruments appear similar. The reason is to be found in the treatment of the more obscure points of design—peak flux density, incremental permeability, hysteresis and eddy losses, ratio of copper weights in primary and secondary, etc.

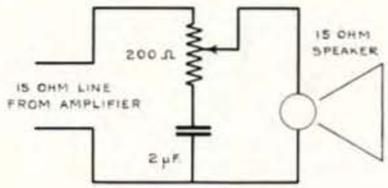


Fig. 18. A tone compensated circuit for controlling the volume of individual speakers.

The Partridge components are designed primarily to give a high fidelity output and a good frequency response happens to be one of their characteristics. A typical curve is given in Fig. 17. Too frequently manufacturers design their audio transformers solely to give a level response, the less obvious necessities for high quality reproduction being overlooked owing to an incomplete understanding of the mathematical analysis of the subject.

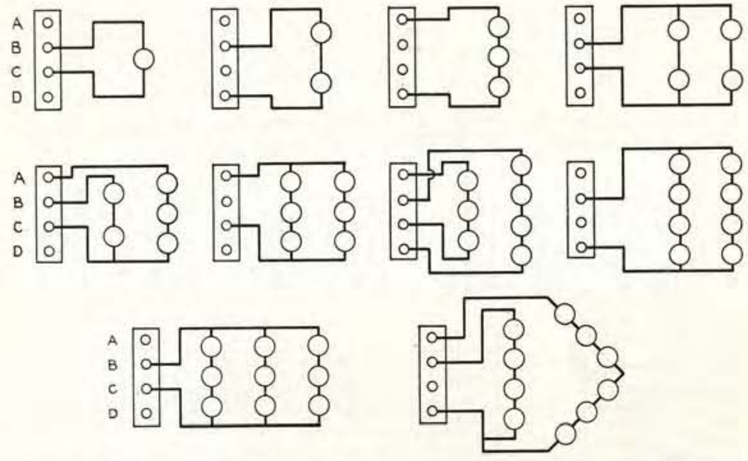
The correct turns ratio is given by the square root of the ratio of the optimum load of the valve (or valves) to the impedance of the speaker or other secondary load. Tappings on the secondary winding should not be used for the highest quality work. The inclusion of tappings in the design, giving a multi-ratio output, does not necessarily spoil the transformer, but the best reproduction will be obtained only when the full secondary winding is in use. The deterioration of quality when using a tapping will depend upon the amount of idle copper (i.e., the number of turns not in use) and the symmetry of the section in use with respect to the primary.

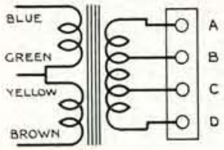
TABLE IV.

Type of Conductor.	Number and Diameter of Strands.	Resistance in Ohms of 100 Yds. Twin Cable.
22 S.W.G. Copper	1/·028	7·80
21 ,, ,, ...	1/·032	5·98
20 ,, ,, ...	1/·036	4·72
19 ,, ,, ...	1/·040	3·82
18 ,, ,, ...	1/·048	2·66
2 Amp. Lighting Flex	14/·0076	7·94
3 ,, ,, ,, ...	23/·0076	4·84
5 ,, ,, ,, ...	40/·0076	2·78
10 Amp. Power Flex	70/·0076	1·58
15 ,, ,, ,, ...	110/·0076	1·00
3 Amp. V.I.R.	1/·036	4·72
5 ,, ,, ...	1/·044	3·16
5 ,, ,, ...	3/·029	2·42
10 ,, ,, ...	1/·064	1·50
10 ,, ,, ...	3/·036	1·58

Varying Loads:—Many occasions arise in practice when it is not possible to operate under the ideal load conditions mentioned above. In radio relay station, hotel and school installations and in the home where extension speakers are used, it is essential to control the volume of individual speakers and to switch speakers out of circuit without altering the ratio of the output transformer. Advantage can be taken of the fact that with triodes in Class A and also in certain Class A—B circuits, the anode load can be increased (never reduced) above the optimum value providing the output power is reduced in the inverse proportion. Suppose four 15 ohm speakers are operating in parallel from a 12 watt output stage. The transformer should be wound for 3·75 ohms (15 divided by 4) and each speaker will receive 3 watts (12 divided by 4) at full output. If two speakers are switched off, the load on the 3·75 ohm output will now be 7·5 ohm (15 divided by 2). However, if no alteration be made to the setting of the amplifier volume control, the power supplied to the remaining speakers will not increase perceptibly and the output power will therefore drop to one-half. Under these conditions no distortion will occur, but if the amplifier volume control is turned up in an attempt to feed the full 12 watts into the mismatched load, harmonic distortion will at once become apparent. Pentodes and many Class B circuits are quite unsuitable for conditions such as the preceding in which the load impedance is varied.

Speaker Volume Control:—The individual volume control of speakers presents a problem. A constant impedance fader is useless because the impedance of the speaker varies so widely with frequency. Similarly a variable series resistance or a potentiometer are both unsatisfactory. The scheme of Fig. 18 is a good compromise. If the potentiometer were used alone the tone would be very thin at low volumes since the speaker impedance is much greater at high than at low frequencies. The condenser partially compensates for this effect by boosting the bass. The values indicated are suitable for a 15 ohm speaker and should be altered proportionately for speakers of different impedances. The value of the condenser can be varied to give more or less bass to suit circumstances.





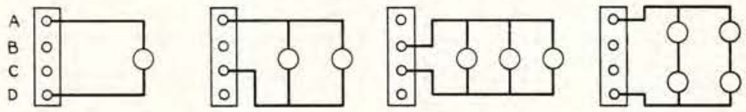
SECTION	OUTPUT IMPEDANCE IN OHMS				
	FOR 1 OHM SPEAKERS	FOR 4 OHM SPEAKERS	FOR 8 OHM SPEAKERS	FOR 15 OHM SPEAKERS	FOR 35 OHM SPEAKERS
AD	3	12	24	45	105
AC	1½	6	12	22½	52½
BD	2	8	16	30	70
BC	1	4	8	15	35

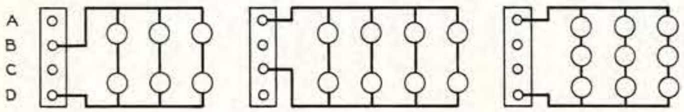
Fig. 19. Method of employing the Series Type Partridge Output Transformer. This scheme can be applied to any output valves, and speakers of any impedance, but all the speakers must be of the same impedance.

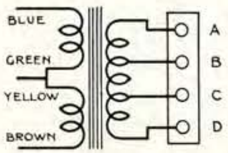
The line between the output transformer and speaker can cause mix-matching and loss of efficiency unless its resistance is low compared with the impedance of the speaker. Line capacity is not important with the usual low impedance speakers, but its inductance must be kept to a minimum by twisting the two leads (go and return) tightly together, otherwise attenuation of the higher frequencies may occur.

Line Resistance:—Suppose a 2 ohm extension speaker is wired with twin 22 S.W.G. bell wire and is about 10 yards away from the output transformer. Ten yards of twin 22 S.W.G. will have a resistance of around 1 ohm, hence the combined impedance of the speaker plus line will be 3 ohms and no less than one-third of the output power will be wasted in the resistance of the line. A line resistance of up to a maximum of 10 per cent. of the speaker impedance is satisfactory.

In public address work groups of speakers are often used at the end of long lines. Consider three 15 ohm speakers. Connected in parallel the combined impedance is 5 ohms and therefore the line resistance should be under 0·5 ohm. In series, however, the combined impedance is 45 ohms and the line resistance can be increased to 4·5 ohms without any detrimental effect. This example illustrates the value of series speaker connections in P.A. work. It enables lighter and consequently less expensive line to be used or alternatively a much longer length of similar lead. The resistances per 100 yards of various twin lines commonly employed are given in Table 4. By the aid of this the resistance of any length can be calculated and a suitable cable chosen for any particular purpose.







SECTION	OUTPUT IMPEDANCE IN OHMS				
	FOR 1 OHM SPEAKERS	FOR 4 OHM SPEAKERS	FOR 8 OHM SPEAKERS	FOR 15 OHM SPEAKERS	FOR 35 OHM SPEAKERS
AD	1	4	8	15	35
AC	½	2	4	7½	17½
BD	⅔	2⅔	5⅓	10	23⅓
BC	⅓	1⅓	2⅔	5	11⅔

Fig. 20. Method of connecting the Parallel Type Partridge Output Transformer. This is recommended where short lines are used and where a single speaker is required more frequently than a number of speakers.

When using a group of speakers close together (series or parallel connected) great care must be taken that they are all arranged in phase, so that at any instant all the speech coils are moving in the same direction either in or out. If this is not done bass will be lacking and the tone balance will be upset.

Multi-Ratio Transformers:—A general purpose public address amplifier must be provided with a multi-ratio output transformer so that the full output power can be concentrated upon one or two speakers or else divided amongst a large number of units as the occasion may demand. It is well known that the performance of an output transformer suffers if a wide range of tappings is provided on the secondary. Considerable experimental work has been performed by Messrs. N. Partridge with a view to overcoming this difficulty and has led to the production of two extremely useful types of output transformer. Either type will match almost any number of similar speakers from one upwards, and a really good frequency response is maintained whatever number is in use. This result has been secured by an unusual scheme of sectionalised windings that ensures an almost symmetrical arrangement of the secondary whichever tapping is in use.

(1) **Series Type:**—This type is particularly useful where long lines are likely to be used. Fig. 19 illustrates how to connect from one to ten similar speakers and also shows the output impedances that are provided to suit speech coil impedances in common use. Each of the arrangements shown forms an exact impedance match between valves and speakers, and all speakers receive equal power. This type of transformer can be supplied to order for use with any specified valves and to match speakers of any impedance.

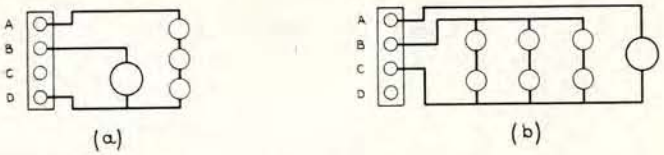


Fig. 21. The speaker connected across B—D in circuit (a) and also that across A—C in circuit (b) receives six times the power taken by each of the other speakers.

(2) **Parallel Type:**—This scheme should be adopted when long lines are not likely to be used and where a single speaker is more frequently in demand than a number. This is illustrated in Fig. 20. All speakers must of course be of the same impedance.

Another use to which the parallel type can be put is shown in Fig 21, in which one speaker is supplied with six times the power taken by the remaining speakers—a useful possibility for many P.A. jobs. Both of the arrangements illustrated form an exact impedance match.

Output Transformer Specifications:—An order should always be precise and leave no room for misinterpretation. The following information must be stated:—(1) the type of output valve (or valves); (2) whether Push-pull or Parallel; (3) whether Class A, A—B, etc.; (4) the impedance (not D.C. resistance) of the speakers; (5) if multi-ratio, whether the Partridge Series Type or Partridge Parallel Type (as described above).

PRE-AMPLIFIERS

A background absolutely free from hum and other noise is not only desirable but essential in any public address system. In the case of high power amplifiers, especially where a choke input to the smoothing filter is employed, this is almost impossible to attain if the equipment is contained in one chassis. An amplifier requiring 0·1v. fully to load the output stage, similar to the Partridge 30 watt and 45 watt amplifiers, can with care be made silent, but a carbon microphone requires slightly greater amplification and it is when an additional stage is attempted that serious troubles arise. Again microphone transformers, tone control circuits for bass boost, and even some types of pick-up cannot be placed near a mains transformer without hum being induced. A separate pre-amplifier overcomes all these difficulties and the results achieved fully justify the small extra expense. It enables the "sensitive" portion of the equipment to be taken a short distance away and completely out of the influence of the mains unit and its unavoidable external magnetic field.

Single Stage:—The single valve circuit of Fig. 22 is the simplest and cheapest form of pre-amplifier. It gives a voltage amplification of 15 from the input terminals to the end of the line, which may be anything up to 50 yards long. This is more than adequate to give a long range with carbon microphones when used in conjunction with the Partridge 30 watt or 45 watt amplifiers described in "Partridge Amplifier Circuits".

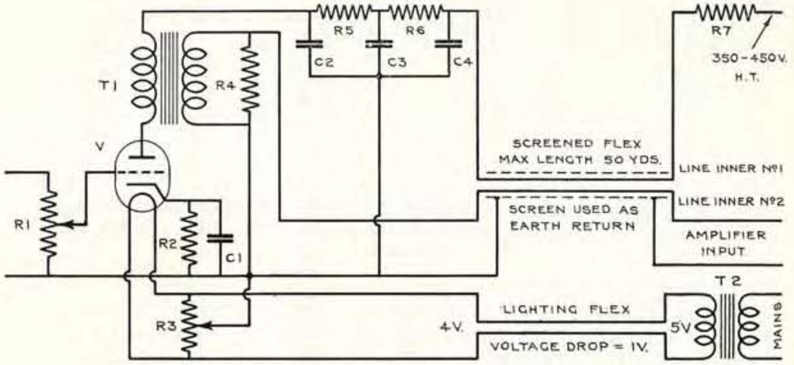


Fig. 22. Partridge Single-Stage Pre-Amplifier. Note the method of using the screened flex and the L.T. line.

The frequency response of the unit is level from 30 to 15,000 cycles (see Fig. 23); this exceptional performance is due entirely to the special output transformer specified. Another important feature is that no step-up transformer is required at the main amplifier end of the line; such a transformer invariably gives trouble with pick-up from the mains equipment.

List of Parts:—

R1	**250,000 ohm potentiometer**	**C1**	**50 m.f. 12v. working**
R2	**300 ohm 1w.**	**C2, 3 & 4**	**8 m.f. 450v. working**
R3	**30 ohm (hum-dinger)**	**V**	**MH41 Marconi or Osram or AC2HL Mazda**
R4	**3,000 ohm 1w.**		
R5, 6 & 7	**15,000 ohm 1w.**		

T1. Partridge Type L4/1.
T2. Partridge Type 5V1/2.

This 5v. filament transformer is not necessary when working in conjunction with the Partridge 30w. or 45w. Amplifiers which are provided with an extra 5v. output for this purpose.

50 yards (less if desired) of screened flex Type 21 from C. Ward, 46, Farringdon Street, E.C.4.

Either 20 yards of 23/·0076 standard 3 amp. lighting flex,

or 40 yards of 40/·0076 standard 5 amp. lighting flex.

Constructional Hints:—The chassis can be made any convenient size and shape from 20 S.W.G. aluminium sheet. The important point is that it must be provided with a screen underneath, so that the chassis forms a closed box. Plywood ½-inch thick, with aluminium sheet tacked on to it forms a good base. The chassis can be made large enough to contain the microphone transformer and batteries if desired.

The filament wires must be twisted together and kept well away from the grid of the valve. The chassis should be connected to the earth line of the circuit at one point only; a position near the valve is a good place. A 5v. transformer on the main amplifier chassis is used for the L.T. supply. This is essential to allow for the voltage drop on the line. Either 20 yards of 23/·0076 standard 3 amp. lighting flex or 40 yards of 40/·0076 standard 5 amp. lighting flex will give the correct drop of one volt when passing one amp. On no account should a filament transformer be mounted on the pre-amplifier chassis.

The only critical component is the transformer T1. This is so designed that the capacity of any length of screened flex up to 50 yards will neither cause attenuation of the higher frequencies nor a resonant rise of voltage at any frequency. See response curves of Fig. 23.

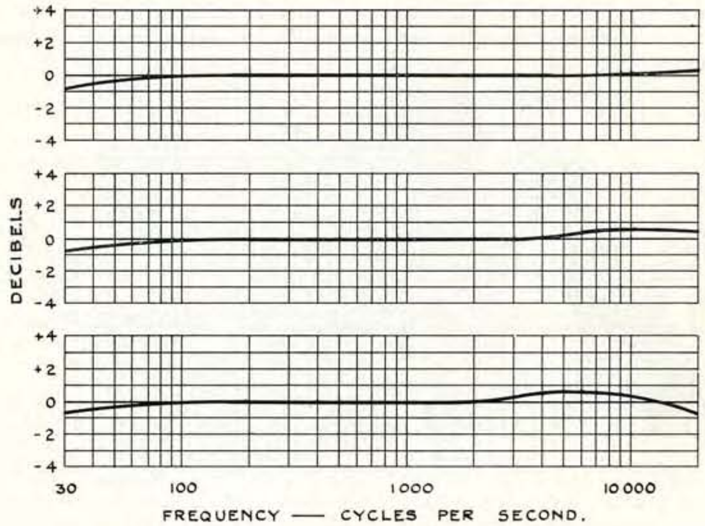


Fig. 23. Response curves of the Partridge Single-Stage Pre-Amplifier with 15, 30 and 45 yards of screened flex. The 15 yard curve is at the top and that for 45 yards at the bottom.

The H.T. can be taken from any convenient point on the main amplifier having a voltage between 350 and 450v. The first 15,000 ohm decoupling resistance is shown at the main amplifier end of the line. This is a good plan as it limits the current should an accidental short circuit occur on the line, and prevents any damage being done to the amplifier as a result.

Operational Notes:—The outer screening of the screened flex is used as a common return for the speech current and the H.T. One inner wire is used for the positive speech line and the remaining one for the positive H.T. The hum-dinger should be adjusted to the position of zero hum.

If the main amplifier volume control is turned fully up a hissing sound will be heard from the speaker. This is valve hiss and cannot be avoided. However, it will rarely be necessary to have the amplifier set to maximum amplification. The method of working is to have the pre-amplifier control always turned well up and to adjust the overall amplification by means of the main amplifier volume control. Do not have the main amplifier control turned right up and as a result work with the pre-amplifier control down at its extreme lower limit.

Modifications:—The unit may be driven by batteries if preferred, in which case R3, R5, R6, R7, C2, C3 and C4 will not be needed. A 120v. battery should be connected direct to the primary of T1 and the earth line. A 4v. accumulator capable of delivering 1a. is suitable for the L.T. Since R3 (hum-dinger) is not used it is essential that one side of the L.T. supply be connected to earth or hum will result.

Mixing and Tone Control:—The pre-amplifier need not be limited to straightforward amplification, as described above, but is a suitable point for mixing incoming channels and also for tone control. The Partridge Two-Stage Pre-Amplifier design allows for mixing two microphones and two pick-ups; each of the four inputs having separate and quite independent controls. In addition the bass and treble can be independently boosted or attenuated. This design was first published in the original edition of the Partridge P.A. Manual, and later in the issues of "Popular Wireless," dated April 17th and 24th, 1937. So important was this original Partridge design considered to be by those competent to judge, that it was selected for review in the "International Broadcast and Sound Engineer."

Full theoretical and constructional details are given in "Partridge Amplifier Circuits," which is obtainable from N. Partridge, B.Sc., A.M.I.E.E., King's Buildings, Dean Stanley Street, London, S.W.1 (price 2/-). This book contains full information for building a number of amplifiers for all purposes, and is a practical guide that no professional or amateur should be without.

THE PARTRIDGE TECHNICAL SERVICE

The Partridge Technical Service aims at providing all the information and technical assistance required to make a satisfactory start and a continued success in the field of Public Address work. It can be divided into four sections:—

(1) **The Partridge P.A. Manual.** This booklet surveys the subject as a whole, and contains much information that can be found only with difficulty elsewhere. The appendix relating to components, etc., is an unusual and useful feature.

(2) **Partridge Amplifier Circuits.** This is a companion volume to the Manual, and can be obtained direct from the author, price 2/-. It contains a number of original amplifier designs especially suited to P.A. work, and the necessary details are given for constructional purposes. All major components are specified, and no previous experience is needed to build the equipment described. A copy of "Partridge Amplifier Circuits" is indispensable to those seeking new and original methods of obtaining quality with economy in power, size, weight and cost.

(3) **Partridge Transformers.** Partridge Transformers are nationally known and need no introduction or comment. However, only actual users can appreciate the prompt service extended to the trade on all types of special windings. If a special design of audio or mains transformer is required, not only will "Partridge" be the most reliable from the technical viewpoint but "Partridge" will be the first to give delivery. All Partridge Transformers are designed by a known authority on P.A., and therefore do not suffer the disadvantages of those components produced by firms whose experience is limited to coil winding alone.

(4) **Free Technical Advice.** All customers building the amplifiers described in "Partridge Amplifier Circuits" are offered free technical advice in the event of any difficulty being encountered. Thus to start building a Partridge Amplifier is to be assured of expert advice until it is satisfactorily completed. The only conditions are that the amplifier shall be built exactly to specification and that 3d. in stamps be forwarded with each query to cover the cost of reply.

It must be understood that the above free service applies only in conjunction with the published Partridge circuits. Special circuits or modifications to suit individual needs cannot be supplied except at a fee proportionate to the work involved.

APPENDIX I.

The following notes concerning supplies, etc., may be of value to those not conversant with the trade.

Resistances:—"Erie Resistors," from ½ to 3 watts are obtainable in all values from Radio Resistor Co., 1, Golden Square, London, W.1, who give a very useful free booklet on technical and design data, upon request. For higher ratings and power potentiometers, Claude Lyons and Bulgin (see General Lists below).

Condensers:—Dubilier Condenser Co., Ltd., Ducon Works, Victoria Road, North Acton, London, W.3, and Telegraph Condenser Co., Ltd., Wales Farm Road, North Acton, London, W.3, both publish very full lists. Used in conjunction almost any type of condenser can be obtained from these two sources.

Transformers:—N. Partridge, King's Buildings, Dean Stanley Street, London, S.W.1, is the only name that can be given with absolute confidence. To design transformers for modern circuits it is imperative to possess an expert knowledge of the whole of amplifier technique; considerably more than experience in transformer construction is necessary. Mr. Partridge is a known P.A. consultant in addition to being a transformer specialist and manufacturer.

Nickel Alloy Transformers:—G. A. V. Sowter, B.Sc., A.M.I.E.E., Consultant and Manufacturer, 18, Bushey Way, Park Langley, Beckenham, Kent (see page 17).

Valves:—Mullard Wireless Service Co., Ltd., 225, Tottenham Court Road, London, W.1; General Electric Co., Ltd., Magnet House, Kingsway, London, W.C.2; Edison Swan Electric Co., Ltd., 155, Charing Cross Road, London, W.C.2. These three companies each have an excellent technical staff, and are always willing to be of assistance as far as valve applications are concerned.

Terminals, Fuses, etc.:—Belling and Lee, Ltd., Cambridge Arterial Road, Enfield, Middlesex, manufacture a very complete range, and also specialise in the suppression of radio interference.

Meters:—Ferranti, Ltd., Radio Works, Moston, Manchester, 10, produce reliable and accurate 2½ inch instruments of all types.

General Lists:—All varieties of accessories are included in the catalogues published by Claude Lyons, Ltd., 76, Oldhall Street, Liverpool, 3; and A. F. Bulgin and Co., Ltd., Abbey Road, Barking.

Secondhand and Surplus Components and Equipment:—C. F. Ward, 45, Farringdon Street, London, E.C.4; Electradix Radios, 218, Upper Thames Street, London, E.C.4.

Speakers:—Benjamin Electric, Ltd., Tariff Road, Tottenham, London, N.17; Goodmans (Industries), Ltd., Lancelot Road, Wembley, Middlesex; Film Industries, 60, Paddington Street, London, W.1; Voigt Patents, Ltd., The Courts, Silverdale, Sydenham, London, S.E.26 (High Fidelity Types).

Microphones:—Probably less is known about available microphones than about any other component. The following table should be valuable to amateurs and professionals alike:—

TABLE V.

Type.	Manufacturer.	Price.	Sensitivity.	Impedance
		£ s. d.	db.	Ohms.
Carbon	M.R. Supplies, 11, New Oxford Street, London, W.C.1	2 15 0	—	450
Carbon Varidep.	Telephone Manufacturing Company, Hollingsworth Works, Martell Road, London, S.E.21	7 7 0	−40	500
Carbon (Round)	Technical & Research Processes, Ltd., 410, St. John Street, London, E.C.1	8 0 0	−50	200
Carbon	Philips (Amplifier Dept.), 147, Wardour Street, London, W.1 ..	10 10 0	−30	30
Moving Coil	Film Industries, Ltd., 60, Paddington Street, London, W.1 ..	5 10 0	−60	35
Moving Coil	Tannoy Products, Guy R. Fountain, Ltd., Canterbury Grove, London, S.E.20	6 6 0	−68	600
Moving Coil	Grampian Reproducers, Station Avenue, Kew, Surrey	6 6 0	−60	20
Moving Coil	Vitavox, Ltd., Westmoreland Road, London, N.W.9	10 10 0	—	30
Moving Coil	Philips (Amplifier Dept.), 147, Wardour Street, London, W.1 ..	12 12 0	−50	30
Ribbon	The Trix Electrical Company, 8/9, Clerkenwell Road, London, E.C.1	12 12 0	−68	200
Ribbon	Grampian Reproducers, Station Avenue, Kew, Surrey	15 15 0	−68	20
Ribbon	Philips (Amplifier Dept.), 147, Wardour Street, London, W.1 ..	18 18 0	−68	250 or 16,000
Piezo B2S.	Rothermel, Canterbury Road, Kilburn, London, N.W.8	10 10 0	−66	2—5 Megohm.
Piezo G4S6P.	Rothermel	30 0 0	−68	2—5 Megohm.

Great difficulty was experienced in obtaining values for sensitivity and although every attempt has been made to give comparable figures, no guarantee can be given as to their accuracy.

APPENDIX II.

Typical Places and Occasions for P. A. Activities:—

Sports Fields.	Restaurants.	Factories.
Race Tracks.	Dining Rooms.	Large Stores.
Skating Rinks.	Night Clubs.	Offices.
Dance Halls.	Roof Gardens.	Hotels.
Swimming Pools.	Road Houses.	Hospitals.
Gymnasiums.	Public Parks.	Schools.
Fairs.	Piers.	Ships.
Carnivals.	Pleasure Gardens.	Docks.
Circuses.	Promenades.	Churches.
Exhibitions.	'Bus and Tram Centres.	Theatres.
Public Functions.	Railway Stations.	Cinemas.
Election Meetings.	Aerodromes.	Garages.
Concert Halls.	Car Parks.	Barracks.

APPENDIX III.

The Uses of Public Address

(1) **Direct Entertainment:**—The simplest use of P.A. is to provide entertainment. It may be the principal interest, as when used to replace a band in a park or on a pier, or it may form a supplementary interest, as when used in a restaurant, theatre, race track, etc.

(2) **Reinforcement of Sound:**—Here the equipment is employed to make the original source of sound more easily audible. Examples are to be found in Theatres, Churches, Dance Halls, etc. In all cases the orchestra or speaker can be seen and heard, but the P.A. gear augments the sound, making listening more comfortable.

(3) **General Announcements:**—This differs from (2) in that the original speaker is not seen or heard directly. For example, at race meetings, announcements are made that can be heard everywhere, but the speaker is hidden from view. In Hospitals, Schools, Hotels, Factories, etc., announcements can be made throughout the building from the central office.

(4) **Reversed Operation:**—A loud speaker can be made to function as a microphone if used with a correctly designed transformer. Hence in Schools, Factories, Hospitals, Hotels, etc., where a general announce system is installed it is a simple matter to reverse the amplifier connections and listen to what is going on at each point where a speaker is installed. This possibility may cause embarrassing situations.

(5) **Control and Direction of the Public:**—Police cars are often fitted with P.A. gear, which is equally useful at 'Bus, Tram, and Railway Terminals and Stations. Further applications are to be found at the entrances to Sports Arenas, Stadiums, Car Parks, etc., as well as at busy traffic points and pedestrian crossings.

(6) **Adding Interest by Commentary:**—At large race and sports meetings interesting things are happening behind the scenes, and carefully placed microphones enable short commentaries to be made, thus holding interest during intervals or dull moments.

(7) **Replacing Expensive Instruments:**—A peal of bells is highly expensive to instal—good records or small bells amplified can sound almost as good at a fraction of the outlay. Similarly, the organ can be reproduced from records or from a miniature instrument amplified.

(8) **Publicity:**—Announcements from a van are often made to good effect, but more subtle methods can be devised. In large stores a P.A. installation can be used to provide a background of soft music interspersed by carefully prepared announcements directing attention to special bargains and to departments that are quiet. At sales times the movement of the crowd can be controlled by suggestion.

(9) **Sound Effects:**—Never has the theatre possessed so versatile an equipment. Any sound can be recorded and reproduced at will. The sound can come from any direction (including from the auditorium) and at any volume. The illusionist should be alive to new possibilities. His confederate can be heard talking within a box swinging high above the audience—but is he inside it ?