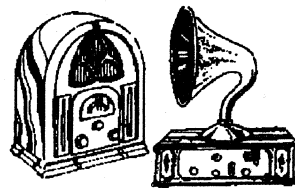


Vintage Radio

by PETER LANKSHEAR



Some popular output triodes — 1

A special group of valves has always been held in high regard by high quality audio enthusiasts. These are the big output triodes, some of which are still in production. This month we look at the first generation of these valves.

Before 1923 and the advent of broadcasting, the concept of fidelity of audio reproduction hardly existed. Headphones were in universal use, and they were judged mainly by their sensitivity. Transmissions were practically all in Morse code, and the prime requirement was audibility. Often receiver audio transformers were tuned to around 1kHz, to improve intelligibility of telegraph signals. In 1920, the only service where audio quality had any meaning was not in radio, but the rapidly expanding telephone repeater technology.

America's Western Electric Bell Laboratories had taken Lee de Forest's erratic Audion triode and by 1915 had tamed it, to become a practical commercial device capable of factory production to close standards. In Europe valve development was accelerated by wartime demands, one very significant result being the famous 'R' valve.

The advent of broadcasting soon created a demand for loudspeakers and, to drive them, valves capable of more than the few milliwatts required by headphones. In Britain, Marconi-Osram had developed from the R valve their type 25, a large valve used by the British Post Office for telephone service. From the type 25, Marconi-Osram produced a family of large triodes, their 'LS' series for loudspeaker work. The LS5A, introduced in 1924, was used by the newly established BBC and became popular with affluent amateurs interested in improving sound quality.

Meanwhile Western Electric had taken one of their wartime valves, the VT2 and in 1917 further refined it to become the 205A, a 'miniature' transmitting valve, capable of handling 300 anode volts. The 205 series underwent several developments, and by 1924 the 205D was in full production.

Western Electric with its research organisation, the Bell Telephone Labora-

tories, was and still is a remarkable organisation. Their prime purpose was to provide the vast Bell Telephone network with its equipment. As well, they are involved in outside commercial undertakings. In Britain and Australasia, they are represented by their affiliates Standard Telephones and Cables (now Alcatel Australia), an organisation I imagine with which most readers are familiar.

Reliability paramount

Not being concerned so much with high volume, low initial cost equipment as with extreme reliability, Western Electric's philosophy for valves has always been very different from the domestic consumer market.

To put this into perspective, in 1978 it

was estimated that replacement of a valve in a submarine repeater could cost \$40,000. Obviously, low initial cost was not significant if it compromised quality and reliability!

It is on record that every one of the 306 Western Electric type 175HQ valves used for the first trans-Atlantic telephone cable operated continuously for 22 years, without a single failure. The later type 455A-F valves were equally reliable. By 1978 there were 5674 of these valves in use, each with an average continuous service of nearly 15 years. There had been only two probable failures and in any event, redundancy of amplifier design meant that service was not affected. Even premium semiconductors would find it hard to beat that sort of record.

This then is the background to the type of organisation that in 1924 produced the 205D. I guess that few readers have handled a 205D, but as we shall see, many will have encountered the 205D in operation.

Favoured by hams

Meanwhile, American General Electric and Westinghouse were developing valves and equipment for RCA. As we related in this column for May 1990, the production of the first practical moving coil loudspeaker depended on the availability of an audio amplifier capable of producing a genuine one watt. This became possible when, in 1924, RCA's UV210, essentially a scaled up UV201A valve, became available. The following year it received the new long-pin base, to become the UX210 and proved to be popular for audio amplifiers and especially with radio amateurs as an oscillator and RF amplifier.

Transmitting versions, the 10Y and 801 were produced. Only with the advent of the equally ubiquitous 807, immediately prior to World War II was the UX210 superseded.

At this stage I would remind readers

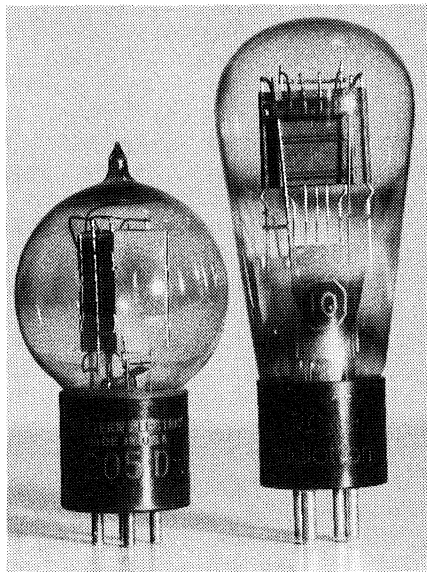
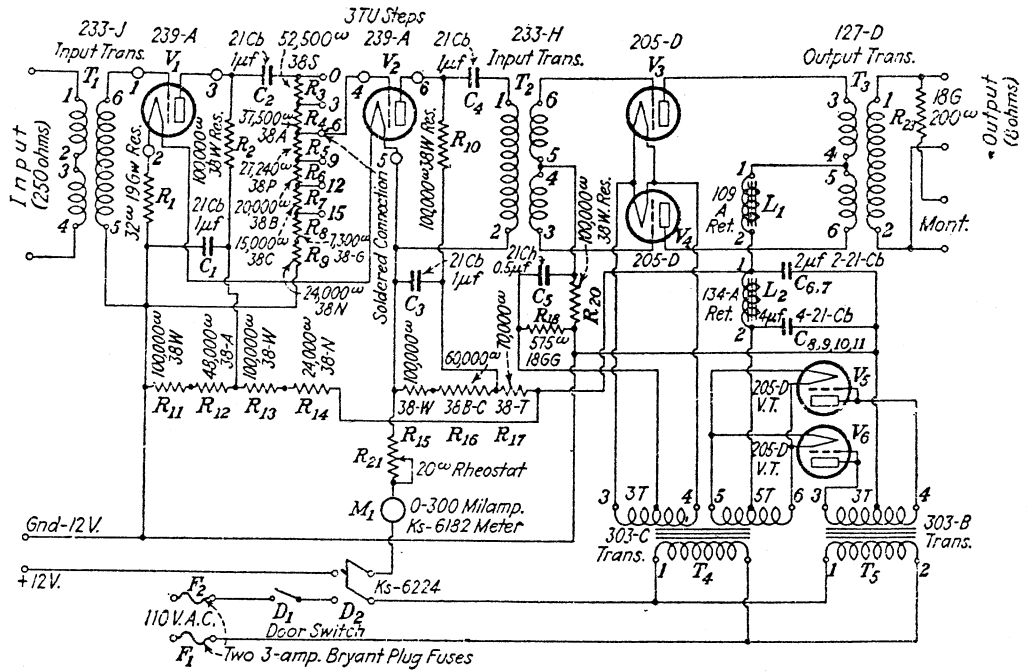


Fig.1: Although the spherical Western Electric 205S and the S-bulb RCA UX210 were very different in construction, their characteristics were comparable. Globular envelopes were a distinctive feature of many WE valves, which had oxide-coated filaments or cathodes.

State of the art audio in the late 1920's: Western Electric 46A amplifiers using 205D triodes as rectifiers, as well as output valves for early 'talkie' sound installations. As WE had not developed an indirectly heated valve, low microphony type 239A and later the 264 series with 1.5V/300mA filaments were used for the voltage amplifiers. The 46A could produce only about four watts, but this was adequate for horn-loaded speaker drivers such as the WE555.



that the original RCA numbering system for valves was clumsy. The prefix UV, UX and UY referred to the base, and the first digit identified the supplier — 1 for Arcturus, 2 for RCA and 3 for Cunninghamham etc. Only the second and third digits had any real significance, and before long the rest was dropped. Thus the UX210 was known as the 10, the UX250 as the 50 and the UX245 became the 45. This abbreviation did not apply to Western Electric valves, which generally had their own system of identification.

Two major developments influenced high quality sound research in the mid 1920's. These were electrical gramophone recording and sound movies, both of which set new standards in reproduction and sound generation. Both the Western Electric and RCA organisations were major players, and good use was made of both the 205D and the 210.

50 years of service

Western Electric designed new amplifiers, including the 42A and 46A, for the 'talkies'. Both used a push-pull pair of 205D valves in the final stage, and were capable of producing three to four watts of audio power. Used with WE 555 horn-loaded speaker drivers, this was sufficient power for small movie theatres. But for larger auditoriums, additional power was provided by the type 43A amplifier, which used a push-pull pair of 211 transmitting valves coasting at a modest 12 watts output!

Many thousands of the 42A and 46A amplifiers were in use world wide, and such was the quality of their design

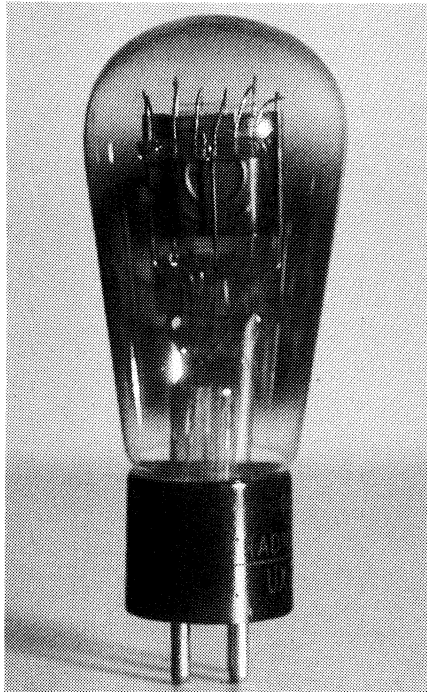


Fig 2: For the best part of three years, the UX245 practically monopolised American receiver output stages.

and construction that some were still in service in the early 1980's! There can be few other types of electronic equipment with continuous service spanning more than half a century, and there must be few readers who have not at some time attended a WE-equipped theatre and heard one of these amplifiers in operation.

By 1928, moving coil speakers were

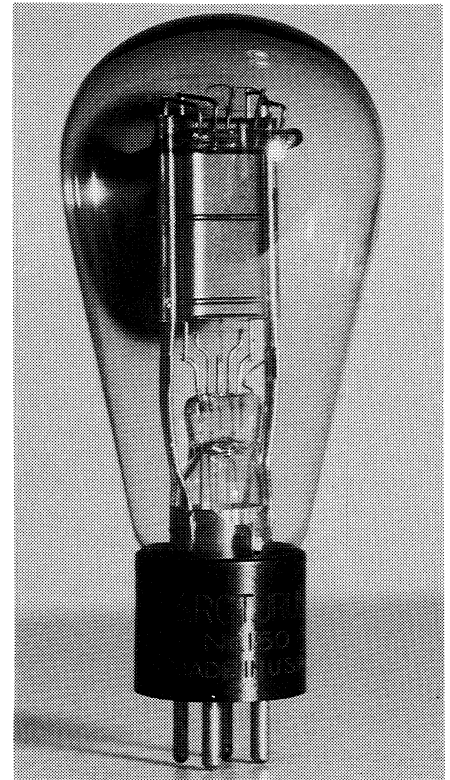


Fig.3: With the largest bulb ever used for American non-transmitting valves, the impressive UX250 was used in some 'top of the line' receivers.

beginning to be widely used, in many cases installed in console cabinets with their improved baffling. More audio power could be used, and in February RCA announced the Westinghouse developed UX250. With the biggest envelope ever used on an American

VINTAGE RADIO

non-transmitting valve, the mighty 50 could develop nearly three times the power output of the 10. Some were used in prestige receivers, but the 50 really belonged in public address and theatre sound systems.

For some years, the 50 was unrivalled in sound systems, but it was really too large and over-powered for most domestic service. A much more suitable valve appeared in 1929. In many respects the junior brother of the 50, the UX245 was an immediate success. Almost always used in push-pull, a pair of 45's could produce up to five watts with only 275 anode volts.

Rule of the 45

Although in Europe and Britain, Philips had introduced the pentode output valve in 1927, the 45 dominated American receiver output stage design for the best part of three years. Not until 1931 did America have a really acceptable output pentode. Even then the 45 continued to be used occasionally, in receivers made for the quality conscious.

By the end of the decade, valve design had progressed considerably. Some significant characteristics are listed in the table. Anode voltage and current are an indication of power handling ability, and being less stressful on capacitors and

VALVE CHARACTERISTICS

VALVE TYPE	AMPL FCTR	ANODE RESIS	MUTUAL CONDUCT	ANODE VOLTS	ANODE mA	POWER WATTS
LS5A	2.5	2750	1.0	400	33	2.6
205D	7.3	3800	1.9	350	30	1.8
10	8.0	5000	1.6	425	18	1.6
50	3.8	1800	2.1	450	55	4.6
45	3.5	1700	2.0	275	35	2.0

The characteristics of the valves described, in typical single-ended operation. Two in push-pull would produce something more than twice the power output.

safer, low voltage operation was an advantage. The 45 could produce as much power as the earlier 205D and 10, but with a worthwhile reduction in anode voltage. The remaining parameters are inter-related.

Amplification factor or mu (μ) provides an indication of the amount of grid signal voltage required to drive a triode valve to full output. In practice, the mu of power triodes is less than 10 and in some cases less than four.

Anode resistance is a measure of the ability of a valve to deliver power to varying loads. This can be illustrated by the differing behaviour of carbon/zinc and NiCad cells.

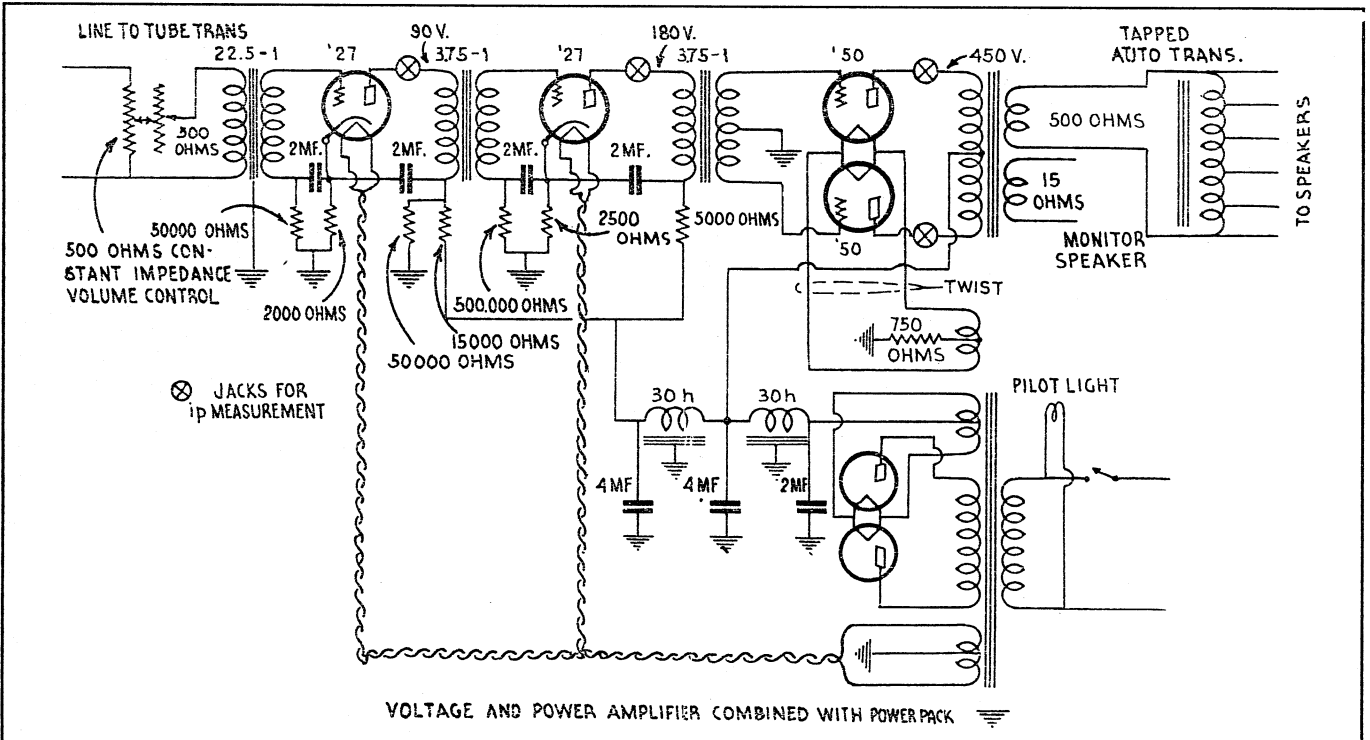
The terminal voltage of a standard dry cell connected to a low resistance falls significantly under load, whereas the

much lower internal resistance of a NiCad cell has little effect on voltage under quite heavy loads. A low plate resistance enables a triode to more readily cope with the extremely variable load presented by a moving coil loudspeaker.

Transformer inductance

Another factor is transformer requirements. For a given low frequency performance, output transformer primary winding inductance requirements are proportional to anode resistance. Referring to the operating conditions given in the table, for the same frequency response, a transformer for a type 10 valve would require 5000/1700 or nearly three times the inductance required for a type 45.

The ideal power triode would therefore have a low anode impedance and a



A typical high powered audio amplifier using a pair of 50's. Transformer coupling was universal, and frequently the limiting factor in reproduction quality. It was commonly thought that grid blocking made R-C coupling of output stages impractical.

high amplification factor; but unfortunately, the two are in conflict. For a given valve geometry, raising the amplification factor increases the anode resistance. The ratio of these two parameters is a constant called, in the American system, the *transconductance* and is measured in micromhos (the same as the modern microsiemens, or μS).

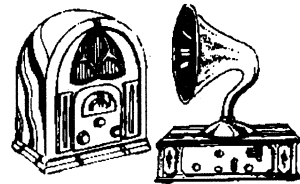
In British terms the same ratio is known as the *mutual conductance* and is expressed in mA/V — the change in anode current, in milliamps, for a change of one grid volt.

Clearer terminology

In my opinion the British terminology provides a clearer concept. Fortunately, regardless of the system used, the result is the same, but it would have helped if the Americans had chosen millimhos (millisiemens, or mS) for the unit, as then the figures in the two systems would have been identical. As it is, in American terms the 45 has a transconductance of 2000 micromhos, whereas the British would quote the mutual conductance as 2mA/V . Despite the apparent difference the two are identical.

I have written at length about transconductance or mutual conductance, because it is the characteristic that can be regarded as a figure of merit for output valves. In 1929, the limit had been reached at around 2.0mA/V , and only by raising this could the output triode be improved.

How Marconi-Osram advanced valve design, leading to the second generation of output triodes, and prevented their complete eclipsing by the pentode will have to wait until the second of these articles. ♦



Some popular output triodes — part 2

Right from the early days of broadcasting, large output triodes have been linked with high quality sound reproduction, and even today are in demand by a select group of enthusiasts — who are convinced that the triode is still unrivalled in providing the ultimate sound. In this second part of the story, we look at some of the 'second generation'.

Last month took us to 1929 and the arrival of the popular type 45 triode. In Holland, Philips research had in 1927, developed the very first of a promising new type of valve: the output pentode, which overcame two weaknesses of the triode — lack of sensitivity and inefficiency. Meanwhile, the trusty 45, generally operating in push-pull, continued to serve America well in the new generation of big mains powered receivers.

The Americans took until 1931 to produce what they considered to be satisfactory pentodes: the Arcturus PZ, followed by the similar RCA 47. With their greater power efficiency and higher amplification factor, the pentodes soon displaced the 45. The Great Depression restricted demand for expensive cabinets, and con-

venience and economy ensured the success of the 'midget' mantel receivers that took their place. With its greater sensitivity the pentode output valve was a natural choice for these new receivers, as no expensive and unreliable interstage audio transformer was necessary.

One characteristic of the pentode assisted its popularity for small cabinets. As we saw last month, a desirable feature of the triode is its low anode resistance which assists in damping speaker cone resonances. Pentodes on the other hand, have a very high anode impedance and in the absence of negative feedback, provide little speaker damping.

The public were becoming aware of the extended frequency range of the moving coil loudspeaker. 'Listen to the

bass!' was a popular advertising slogan, but the shift from console cabinets to the limited speaker baffling of small cabinets restricted low frequency performance. However, there was some low fidelity compensation from the pentode's lack of damping, which permitted cone resonances to boom away without inhibition — increasing the apparent bass performance.

Despite its inferior fidelity, the pentode was rapidly accepted and, together with the later beam tetrode, dominated output stage design right to the end of the valve era.

British breakthrough

But back to 1929. Although an improvement on its predecessors, and quite popular, the recently introduced type 45 nevertheless had some serious limitations. As with most engineering, valve design was a compromise. Amplification factor in triodes had to be traded against anode resistance. A low anode resistance was desirable, but it was achieved at the expense of amplification factor, and therefore sensitivity.

For example, a push-pull pair of 45's with an amplification factor of only 3.5 needed at least 100 volts grid-to-grid drive, for full output. This placed considerable demands on the driver valve, whose distortion could easily exceed that of the output stage. Transformer coupling eased the problem considerably, but good quality examples were very expensive.

The only way to raise the amplification factor of a valve without sacrificing low anode resistance was to increase the mutual conductance. This could be achieved by reducing grid to cathode spacing, which was difficult to do reliably with existing assembly methods, or alternatively by increasing the cathode area.

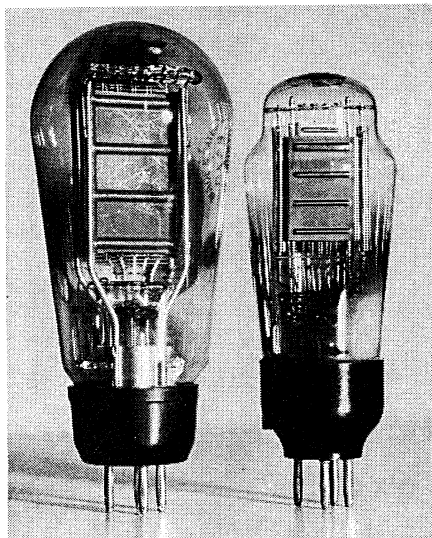


Fig.1: Marconi-Osram's PX4 of 1929 represented a major advance in British power triode development, and was copied by other makers. A typical example is the Cossor 4XP, on the right. At left is the massive PX25, the largest PX4 derivative and a favourite British power triode.

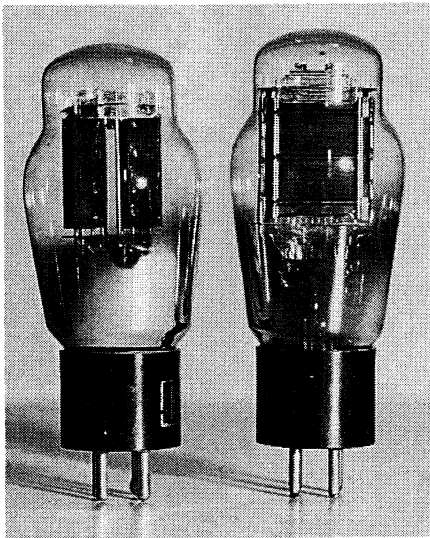
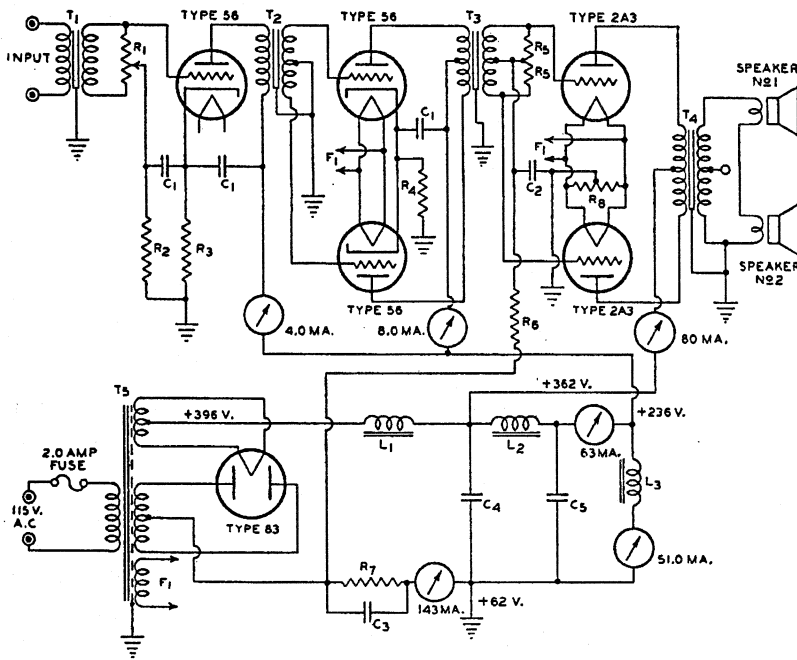


Fig.2: The original American 2A3 on the right had much in common with the PX4, but with a 20-strand filament (the bottom row of hooks is just visible below the anode). On the left is the later and more common pattern, which is effectively two identical triodes connected in parallel.

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- $C_1 = 1.0 \mu\text{f. (200 V.)}$
- $C_2 = 20.0 \mu\text{f. (75 V.)}$
- $C_3 = 10.0 \mu\text{f. (75 V.)}$
- $C_4 = 10.0 \mu\text{f. (400 V.)}$
- $C_5 = 4.0 \mu\text{f. (300 V.)}$
- $R_1 = 250,000 \text{ OHMS (VOL CONTROL)}$
- $R_2 = 100,000 \text{ OHMS}$
- $R_3 = 2,200 \text{ OHMS}$
- $R_4 = 1,100 \text{ OHMS}$
- $R_5 = 0.5 \text{ MEGOHM}$
- $R_6 = 50,000 \text{ OHMS}$
- $R_7 = 430 \text{ OHMS (5 WATT)}$
- $R_8 = 20 \text{ OHMS, CENTER TAPPED}$

- $L_1 = \text{FILTER CHOKE; } 236 \text{ OHMS, } 12 \text{ HENRIES AT } 140 \text{ MA.}$
- $L_2 = \text{SPEAKER FIELD; } 125 \text{ VOLTS, } 2,000 \text{ OHMS}$
- $L_3 = \text{SPEAKER FIELD; } 175 \text{ VOLTS, } 3,400 \text{ OHMS}$
- $T_1 = \text{INPUT-TO-GRID TRANSFORMER}$
- $T_2 = \text{PLATE-TO-PUSH-PULL-GRID TRANSFORMER}$
- $T_3 = \text{PUSH-PULL-PLATE-TO-PUSH-PULL-GRID TRANSFORMER}$
- $T_4 = \text{OUTPUT TRANSFORMER; PLATE-TO-PLATE IMPEDANCE = } 4,000 \text{ OHMS}$
- $T_5 = \text{POWER TRANSFORMER; SHOULD HAVE GOOD VOLTAGE REGULATION CHARACTERISTICS}$

NOTE: SPEAKERS ESPECIALLY DESIGNED FOR HIGH POWER ARE RECOMMENDED. CIRCUIT CONSTANTS SHOULD CLOSELY APPROXIMATE THOSE GIVEN ABOVE FOR SATISFACTORY RESULTS.

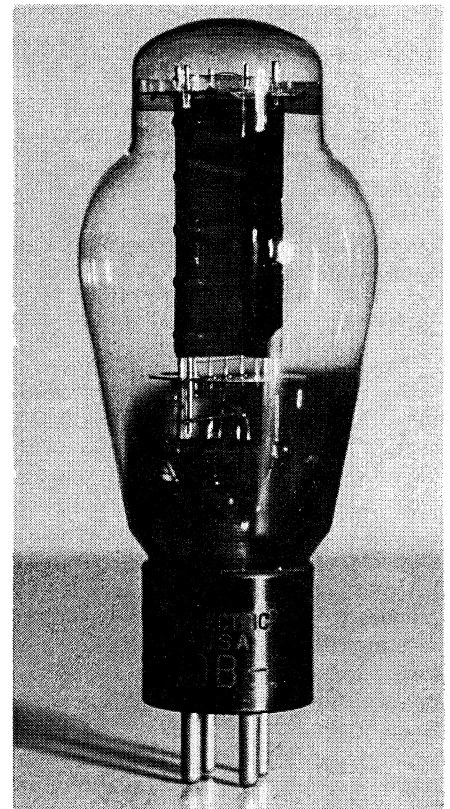


Fig.3: 1933 saw the final development of the traditional power triode. For many enthusiasts the Western Electric 300B, still in production after 60 years, is the finest of its type ever produced.

From the RCA tube manual of 1933, this circuit is typical of American triode amplifier practice in the early 1930's. Transformer coupling simplified the problems of providing sufficient drive for the output stage, but were prone to hum pickup. High quality transformers were also extremely expensive.

In October 1929, shortly following RCA's announcement of the 45, Marconi-Osram in Britain released the excellent PX4. This was to become the first of the new generation of output triodes, achieving a mutual conductance figure of no less than 6mA/V — three times that of the 45 — together with a 40% increase in amplification factor and a considerable increase in power output.

Element spacings were reduced, but most significantly, the cathode area was substantially increased. Whereas output valve filaments previously had been 'M' shaped with four strands, the PX4 had eight strands in a double-M formation.

The improvement was impressive. With an anode resistance of only 830 ohms, an amplification factor of 5, and anode dissipation progressively up-rated from 10 watts to 15 watts, a single PX4 was eventually capable of producing nearly twice as much audio power as a 45, but with less drive voltage. In push-pull, a self biased pair with 350 volts

HT supply was rated at 14 watts output. The PX4 was to remain in the catalogs until about 1960, 30 years after its debut.

Other British valve makers soon produced their equivalents of the PX4, and — true to form — used their own identification systems. Cossor barely dis-

guised their version as the 4XP; Mullard made the ACO44; Ferranti produced the LP4, Mazda the PP3/250 and Tungram had the P12/250. British researchers had been working on new pentodes also and by 1931 England led the world in output valve design.

In 1932 Marconi-Osram produced the gigantic PX25, the suffix '25' referring to the anode dissipation of 25 watts. With a mutual conductance of no less than 7.5mA/V and an amplification factor of 9.5, the PX25 was a considerably im-

SINGLE VALVE: TYPICAL CHARACTERISTICS

TYPE	ANODE VOLTS	ANODE mA	ANODE RES	AMP. FACTOR	GRID BIAS	MUTUAL COND	POWER O'PUT
50	450	55	1800	3.8	84	2.1	4.6
PX4	300	50	830	5.0	45	5.0	3.5
PX25	500	50	1265	9.5	50	7.5	8.5
2A3	250	60	800	4.2	45	5.25	3.5
300B	300	62	700	3.8	58	5.4	4.5
KT66	400	62	1450	8.0	38	5.5	5.8

The published characteristics of valves were somewhat idealised. Production tolerances could vary 25% above or below the nominal figure.

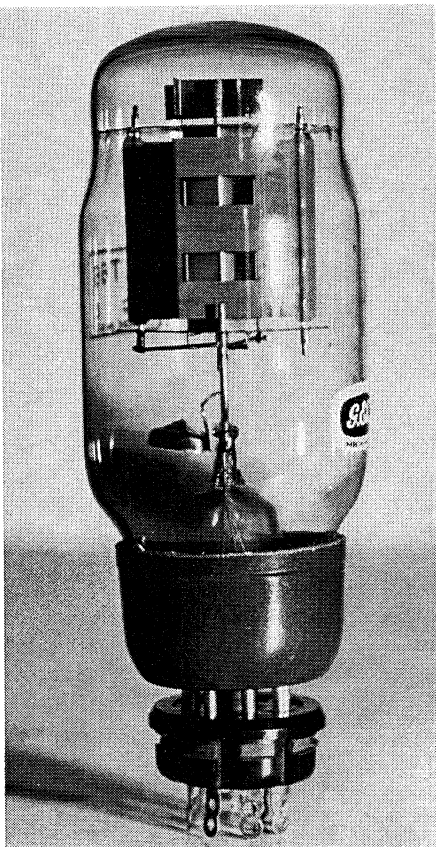


Fig.4: Although a very successful beam tetrode, Marconi-Osram's KT66 achieved considerable international popularity as a triode in amplifiers like the Williamson.

vapour rectifiers. Had the cathode been insulated from the heater, grid biasing might have been simplified, but as it was these valves soon vanished.

Greatest triode of all

The 2A3 family was the last, but very successful, effort by the American RMA in producing big low impedance audio triodes. Later there was to be an unusual output triode that eventually faded into oblivion. The 2B5/6B5 and later equivalent 6N6G had such a high amplification factor that they required a positive grid bias! This caused the grid to draw several milliamperes of continuous current, via a direct coupled small triode in the same envelope — incidentally probably the first commercial application of the cathode follower. These odd valves were efficient, but with an anode resistance of 24,000 ohms, behaved generally more like pentodes.

Western Electric had meanwhile been taking stock. Their aging 205 series described last month was, by 1932, inadequate for any but the lowest powered applications, and alternatively, to use transmitting triodes for medium powered

installations was clumsy and inefficient. It has been claimed that, to produce no more than 12 watts of audio, the old 43A amplifier consumed 325 watts of power!

Western Electric developed a new triode, the magnificent 300A, commencing production in 1933. To permit its use in amplifiers using the earlier skirted socket, in 1938 there was a modification in the form of a small pin inserted in the side of the base. Otherwise unchanged but renamed the 300B, this remarkable valve has the same amplification factor and power handling capability as the 50 but with greater efficiency, and an even lower anode resistance than the 2A3. With a similar sized anode to the PX25, the 300B also has the eight-strand double M filament and looks very impressive in its large and shapely ST19 bulb.

STC for a while also made their version, the 4300B. These superb valves, largely hand made by craftsmen, were made available for public sale and are regarded by many devotees as the finest audio output triode of all time. A push-pull pair operating with 325V on the anodes can deliver 15 watts for a power consumption of only 50 watts.

Note that I use the present tense. I understand that the 300B is still in production, although under the brand name 'CETRON'. Valve manufacture ceased at Western Electric's Kansas City plant in 1988, 55 years after the introduction of the 300A, and to the 300B went the distinction of being the last type produced there.

If I have tempted perfectionist audiophiles to contemplate modifying their favourite amplifiers to take 300B output valves, be warned. The US list price of a single 300B is \$170. According to my calculations, the Australian price for a set of four works out at about \$950 without freight! Compare this with a set of Chinese-made 2A3 valves costing about \$110.

Honorary triode

There were to be no more big triodes. Any further improvements would have been marginal and multi-grid valves were by now quite suitable for most applications, and could be operated as triodes if required.

The next major development in this story was the 6L6 beam tetrode released by RCA in 1936, and capable of turning out massive amounts of power efficiently. Negative feedback enabled these new valves to provide a fidelity comparable with triodes, but with greater efficiency.

Marconi-Osram the following year created their own series of 'kinkless

Collector's Corner

Wiring Diagram Wanted:

I am the Scout Leader at Newmarket Scout Group, and we have just acquired an old AWA Wave Meter Class C, No.1, dated 1942. It tunes from 1470kHz to 10.260MHz, in three ranges. We would really appreciate a copy of the original circuit and/or wiring diagram, so we can restore it to operational condition. Can anyone help?

John Parkin, 49 Barwood Street, Newmarket Queensland 4051.

tetrodes'. The largest was the KT66, equivalent to the 6L6, but with increased voltage and current ratings. As a triode, with the screen grid and anode connected together through a 100-ohm resistor, the KT66 had comparable characteristics to the PX25, but with the advantage of an indirectly heated cathode (by now this was possible for large valves).

This application may have been confined to footnotes on valve data sheets, but for the work a decade later by D.T.N. Williamson. As related in this column for July 1990, he gave details in the April and May 1947 issues of *Wireless World* of an amplifier using a pair of KT66 triodes, which was to set new standards of performance.

Such was the reputation of Williamson's design internationally, that through it the KT66 enjoyed considerable popularity. It is likely that because of this at least as many, if not more, KT66's were used as triodes than as beam tetrodes. So although the KT66 is only an 'honorary triode', it seems a worthy example to conclude this saga. ♦

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