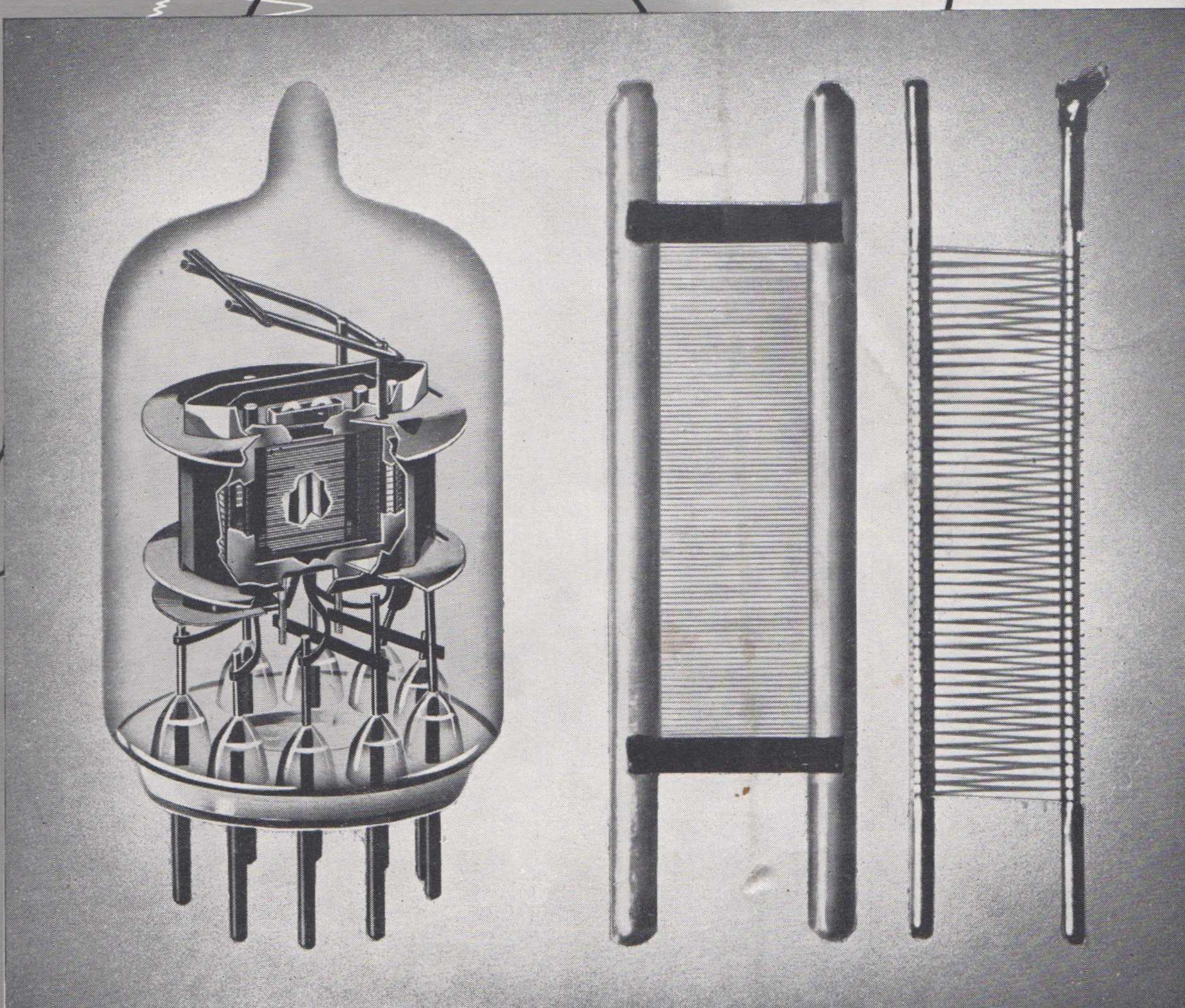
Mullard Outlook

Australian Edition



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1958

Mullard

MULLARD-AUSTRALIA PTY. LTD.

VOL. 1 – No. 6 NOV.-DEC., 1958

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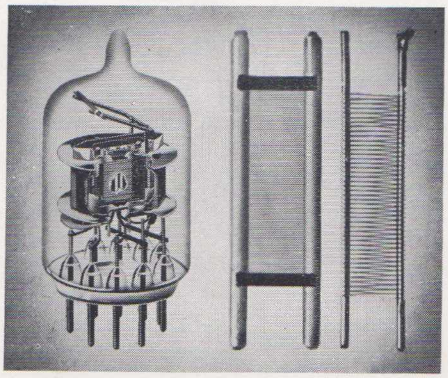

Our cover picture gives a comparison between conventional and frame grid structure. Frame grids have been used in various Mullard valves for some time, as illustrated by the E180F.

More comprehensive information is given on Page 58 of this issue.

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In the constant search for a television receiver cabinet of more aesthetic proportions to better harmonise with typical domestic decor, television design engineers have been faced with the problem of developing shallower television receiver chassis.

As with the normal direct view picture tubes a reduction in length implies an increase in the deflection angle; and a brief survey reveals that in twenty years this angle has increased from 55° to 110°, to a large extent as the result of the requirements of cabinet design with increasing picture tube sizes; this increase in deflection angle poses additional problems for the electronic designer.

With the introduction of 110° picture tubes to Australia, even further refinements of techniques and higher circuit efficiencies are demanded.

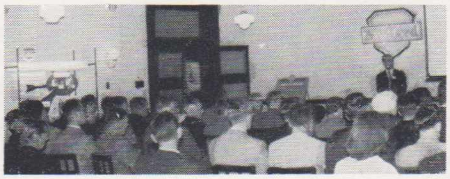
Future issues of the "OUTLOOK" will examine the aspects of television receiver design related to these wider deflection angles, and this issue includes a precis of the present position with abridged data on the valve types necessary to cope with the scanning requirements of 110° television receivers.

VIEWPOINT WITH MULLARD

ORANGE MEETING

On 28th October the thirteenth "Viewpoint with Mullard" was held at the Hotel Canobolas in Orange.

Approximately sixty guests were present and including dealers from Wellington, Parkes, Bathurst, Canowindra, Cowra and Blayney. Mr. Stan White, the well-known Nyngan Dealer, even travelled the record distance of 190 miles to be present at the function.



A section of the audience at the ORANGE "VIEWPOINT" being welcomed by Mr. P. C. Bidencope, of Maintenance Valve Sales Dept.

The wholesale trade was also well represented and included Mr. G. Mitchell, Director, Martin de Launay Pty. Limited (Mullard N.S.W. Distributors) and Mr. E. Beames, Country Sales Manager. W. G. Watson and Company were represented by Messrs. F. R. West, General Manager, W. L. Welsh, Sydney Manager, in addition to Mr. and Mrs. W. S. Gough and Mr. G. Krause from the Orange Branch.

John R. Goldthorp, Mullard Application Engineer, talking with Mr. E. Crouch, Chief Engineer Orange Broadcasting Station 2GZ.

Mullard personnel included Messrs. P. C. Bidencope (Maintenance Valve Sales), J. R. Goldthorp (Applications Engineer), R. Webb (Applications Laboratory) as well as Messrs. R. H. Rabbidge, L. W. Davey (Representatives) and B. Cortaville (Sales Office).

In welcoming the guests Mr. P. C. Bidencope said that it was gratifying to see so many retailers present, especially those who had come so far from the outlying areas to attend. He outlined the services available from Mullard, such as technical data, publications, films, displays, etc., and then introduced Mr. Goldthorp who demonstrated the now familiar Mullard High Quality valve amplifiers, together with a 10W transistorised amplifier, and also the 40W unit which made its inaugural appearance at a recent Brisbane "Viewpoint" Meeting.

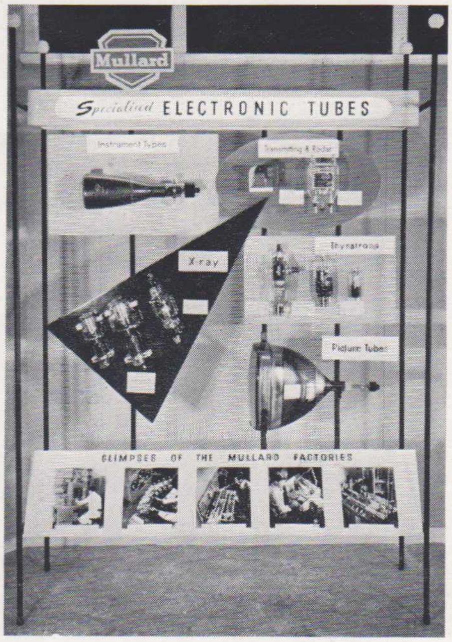
A record number of questions, both of a technical and general nature, were asked by the guests during the evening and a keen interest was evident. Two films were screened by request, namely "Principles of the Transistor" and "Made for Life" both of which were enthusiastically received.

l. to r.
Mr. Hogan of Cumnock, Mr. Martin of Martin-Taylors, Cowra, and Mr. Hall of Broadcasting Station 2CR Cumnock, inspecting the Mullard display of specialised electronic tubes.

Two new Mullard displays were on view at the function, one concentrating on specialised types of electronic tubes, the other featuring a selection of Mullard valves ranging from the original ORA produced about 1920 to present-day types. Further details of this latter display will appear in our next issue.

Numerous technical leaflets and publications were also available for the guests.

NEW MULLARD DISPLAY



The display illustrated above features a selection of the more specialised electronic tubes available from Mullard. The X-ray tubes in the centre panel are of a type currently used in the electro-medical field. The excellent resolution obtainable with these tubes was illustrated by photographs on Page 22 of the "OUTLOOK" for May/June this year.

The pictures at the base of the display show some of the intricate and exacting processes carried out in the manufacture of valves, electron tubes and semiconductors. The right-hand top panel shows a magnetron such as is used in modern marine radar applications, together with a medium sized transmitting triode. The above display is available on a loan basis on request to Mullard-Australia Pty. Ltd., Box 2118 G.P.O., Sydney.

HIGH QUALITY AMPLIFIER LEAFLETS

In order to cater for the high demand for information on the Mullard range of amplifiers and pre-amplifiers it has been necessary for us to produce a number of four-page leaflets giving parts lists and constructional details. The following leaflets are available:—

- 3-3 Quality Amplifier
- 5-valve 10W High Quality Amplifier
- 5-valve 20W High Quality Amplifier
- Single Valve Pre-Amplifier
- 2-valve Pre-Amplifier
- 3-valve Pre-Amplifier

Copies may be obtained on request.

Mullard

WIDER ANGLE PICTURE PRESENTATION AND MULLARD

With the introduction to the Australian market of television receivers employing picture display on 110° deflection television tubes, a number of technical problems, associated in the main with scanning circuits and E.H.T. generation, present themselves to the Design Engineer. These problems are in addition to the electron-optic design requirements for wider angle picture tubes and of course, due to the more arduous operating conditions in line and frame output stages, the production of associated valves with peak voltage and current ratings suited to the task. All these factors must be achieved whilst maintaining the high degree of performance and reliability we have come to expect in television receivers with narrower deflection angles and we believe Mullard valves, semiconductor rectifiers and radiant screen picture tubes, the abridged data for which appears opposite, fully meet these requirements.

Analysis of this data reveals that the 6CM5/EL36 and 1S2/DY86 cope nicely with the more stringent requirements of 110° deflection systems, whilst a new low impedance pentode the 6CW5/EL86 is available for frame output service.

In some line output circuit designs the 6R3/EY81 booster diode will have adequate ratings, but where it becomes necessary for the diode tap to be higher up the transformer a new valve with improved peak voltage ratings, the 6AL3/EY189 may be preferred.

The higher volt-ampere requirements of 110° scanning yokes implies increased power input to the scanning generators of a television receiver, and this in turn necessitates further evaluation of the mains rectifier system. Recent advances in semi-conductor manufacture have resulted in silicon junction rectifiers of suitable rating becoming an economic solution to this problem, and the OA210 with a peak inverse rating of 400 volts is intended for mains rectification in a voltage doubling circuit.

With the 6CW5/EL86 replacing the pentode section of the 6BM8/ECL82 for frame output service a triode valve section is lost, and if we are to maintain the same circuit configurations which have been used in narrower angle receivers, a triode valve section must be added elsewhere in the receiver valve line up. This is accomplished in the 6DX8/ECL84 which is a video pentode with a higher figure of merit than the 6CK6/EL83, together with a triode section having a mu of 65.

The picture would not be complete without mentioning the AW53-88 and the AW43-88 which are 110° radiant screen television tubes with compatible electron-optical systems. This feature, together with the close adherence of other ratings, enables common yoke and line output transformer design for both 21 in. and 17 in. 110° receivers—a factor of which we are sure the industry will approve. Comprehensive data on all Mullard valve types is available through the Technical Service Department and Design Engineers are invited to discuss their problems with the Engineers of our Applications Laboratory.

MULLARD VALVES AND RADIANT SCREEN TELEVISION TUBES FOR WIDER ANGLE PICTURE PRESENTATION

TYPE	DESCRIPTION	HEATER	Va	Vg_2	$—Vg_1$	Ia(mA)	Ig_2(mA)	μ	gm(mA/V)	REMARKS
IS2	Half-wave Rectifier for E.H.T. service.	1.4V	P.I.V. 22kV	—	—	0.8 max.	—	—	—	Data for typical television service. C max. 2000 pf.
6AL3	Booster Diode for line output stage	6.3V	Peak 6kV	—	—	Peak 550.0	—	—	—	Peak Heater-cathode rating 6.6kV. Ia max. 175mA.
6CM5	Power Output Pentode for line deflection service	6.3V	220	160	—	90.0	38.0	—	11.0	Data for typical television service. Peak anode voltage 7kV, Ik 200mA (max.). It is recommended that designers consult the nomogram for the value of peak anode current at the knee voltage for a particular value of screen grid current.
6CW5	Low impedance Power Output Pentode for frame deflection service	6.3V	220	180	—	56.0	6.0	—	10.0	Data for typical television service. It is recommended that designers consult the nomogram to determine the peak anode current at the knee voltage for a particular screen grid potential.
6DX8	High-Mu Triode	6.3V	200	—	1.7	3.0	—	65	4.0	Suitable for synchronising and A.G.C. circuits.
	Video Output Pentode		220	220	3.4	18.0	3.1	36 (g_1 — g_2)	10.0	C_{out} 4.5pf, C_{in} 9.0pf, C_{a-g1} 0.1pf.
OA210	Silicon Junction Diode for 127V rectifier service	—	127V (RMS)	—	—	5.0A pk. 0.5A (averaged over 50ms)	—	—	—	P.I.V. 400V, Inverse Current at P.I.V. = 45μA. Recommended for voltage doubler applications with mains transformers having 127V secondary.

TYPE	DESCRIPTION	FOCUS	SCREEN	HEATER	—Vg	Va_1	Va_3 (Focus-electrode)	Va_{2+4}
AW53-88	21 in. screen, 110° Deflection Angle.	Electrostatic (straight gun)	Metal backed (no ion trap)	6.3V, 300mA	30—72 (for visual cut off)	300V	0–400V	16kV
AW43-88	17 in. screen, 110° Deflection Angle.	Electrostatic (straight gun)	Metal backed (no ion trap)	6.3V, 300mA	30—72 (for visual cut off)	300V	0–400V	16kV

FRAME GRID VALVES

The variety of devices which go under the name of 'valve' is immense: variety not only of size and shape (for example, the subminiature pentode and the klystron), but also of structural detail. If one looks, for instance, at bases, there is a bewildering array which takes in 'pee-wee' and 'super-jumbo' and a multitude of arrangements of leads and lugs.

Grids, perhaps, are even more diverse, with little but their general function of control in common. There is not much physical similarity between the fanned-out structure of loops which was used in certain very early receiving valves, the straight rods of the octode, the beam plates of the power tetrode, the stiff hairpin of some small thyratrons, the perforated disc of larger types, the elegant structure of almost invisible wires in the first disc-seal valves (such as the war-time CV90), and the familiar cage—round, rectangular, lozenge-shaped—of conventional receiving types.

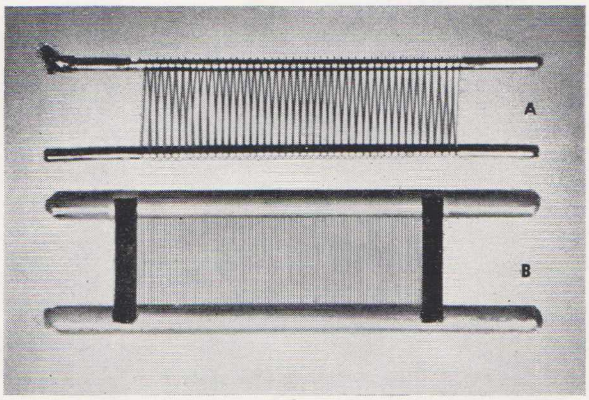


FIGURE OF MERIT

This is a term which has had a number of different definitions. In r.f. circuits it is used as an indication of the bandwidth over which the required amplification of the stage can be obtained. So far as valve characteristics are concerned, the requirement is that the ratio of slope to interelectrode capacitance shall be as favourable as possible, so that each mA/V of slope shall be obtained at the lowest possible cost in capacitive loading. In practical valve design a favourable ratio is achieved by pushing up the slope to a high value, even though the means used to achieve a high slope may, in fact, also produce **some** increase in capacitance.

HIGH SLOPE

The slope of a valve is determined very largely by the control grid. It is a measure of the efficiency with which the grid controls the flow of electrons. A relatively 'inefficient' grid can be found in the television picture tube, in which the grid (a plate with a simple circular hole) requires something like –100 volts to reduce two or three hundred micro-amps to zero. The slope of a c.r.t. may be of the order of 50μA/V, which is sufficient for its purpose.

At the other extreme is the Mullard E180F, which is an r.f. pentode for use in wideband amplifiers in telephone carrier systems, radar sets, and measuring equipment. A 40mA anode current is reduced to zero by only –3 volts, and the slope at the working point is 16.5 mA/V. The E88CC, a double triode for use in cascode circuits and as a multivibrator and cathode follower in computers, has a slope of 12.5mA/V.

FRAME GRIDS

The three types just mentioned achieve their high slopes (and high figures of merit) by means of the frame grid. An efficient grid implies a small grid-to-cathode spacing, and a close mesh of very thin wires. Broadly speaking, the smaller the grid-to-cathode gap, the higher the figure of merit. Thus the problem becomes a question of structural design.

A typical frame grid for a receiving valve consists of two stout rods of molybdenum which are held rigidly apart by stiff cross-pieces. The dimensions of this frame are very closely controlled. For example, the main rods are drawn to size within limits of ±0.005mm. The grid wire is wound on the frame under tension (about 15 grams) and is anchored to the frame at each end. The tension of the wire is sufficient to maintain the accurate spacing of the windings. Gold-plating of the entire structure may be used as a precaution against grid emission.

A frame grid thus consists of two exactly parallel flat meshes of taut wire. The grid is threaded over the cathode in the usual way. Since the distance between the two meshes can be accurately predetermined by a suitable choice of rod size, the clearances between the meshes and the two faces of the cathode are also accurately controlled. The flatness and rigidity of the meshes allow very small grid-to-cathode clearances to be used; and the thin wires (which in a normal grid structure would not be self-supporting) allow the grid to have the greatest electrical effect with the least physical obstacle. High slopes are possible without risk of grid-to-cathode short-circuits. Also the valve characteristics are better determined than would otherwise be possible.

The input capacitance of the valve may be higher with this technique; but the great increase in slope more than outweighs it, and an increased figure of merit is obtained.

STRUCTURAL ACCURACY

Accuracy in the grid structure implies, of course, accuracy in other components—notably the cathode and the spacing micas. Much use is made in frame-grid valve manufacture of optical techniques, such as assembly and inspection under the microscope, and projection of large images of components on to a carefully-dimensioned blown-up drawing.

WIDER VIEW

Frame grids are not new, they are not all of the kind which has been described, and their use is not limited to receiving valves. Fully-fledged frame grids were used as far back as 1943, and recognisable ancestors can be found in the suppressor grids of some pre-war screened pentodes. Some present-day types use ring-like frames; and the Mullard QQV02-6, a double tetrode transmitting valve, has two separate frame grids (one for each tetrode) mounted on opposite sides of the shared cathode. Some manufacturers have used either punched plates or one-piece boxes and have thus eliminated the need for welding.

A discussion of the relative merits of the various kinds of frame, as well as a great deal of background information, can be found in the 'Bell System Technical Journal' for October 1951.

APPLICATION OF VOLTAGE REFERENCE TUBES

Many of the considerations relating to the application of stabilisers apply equally to reference tubes. There are, however, some individual matters which should be clarified.

Invariably, the choice of the actual value of reference voltage is of little consequence, as the prime object is to have a strictly stable source. Where some specific voltage is required, a fraction of the available reference voltage can be obtained by an accurate potentiometer provided that negligible current is drawn.

For these reasons Mullard specify the 85A2 as the preferred reference tube.

In order to obtain the optimum performance from a reference tube it is essential to ensure that the current drawn by it is appreciably constant.

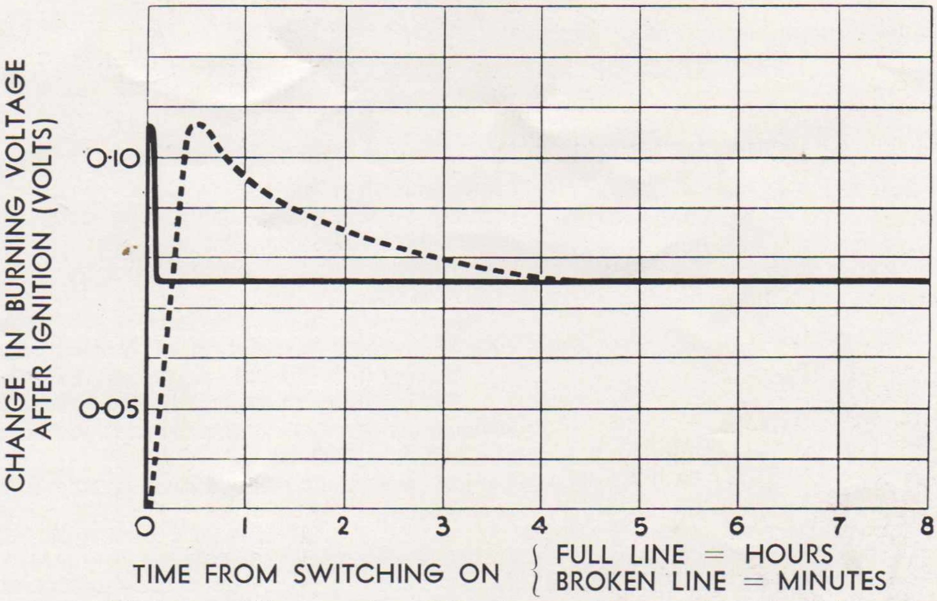


Fig. 2. Eight hour stability curve of an 85A2 reference tube operated at 6.0mA after ageing for 100 hours or more at 6.0mA.

CONSTANT CURRENT SUPPLY

For example, an 85A2 which has been aged for about a 1,000 hours has an inherent stability of better than 0.1% per 1,000 hours. However, the incremental resistance of such a tube is of the order of 300Ω. The variation in burning voltage caused by changes in current through this resistance should be small compared to the inherent stability; a change of 0.1 milliamp can cause a change of 0.03% in effective burning voltage.

Where a direct reference is needed the circuit shown in Fig. 1 may be adopted. A d.c. input of 275 volts is used and a 150B2 tube stabilises this supply.

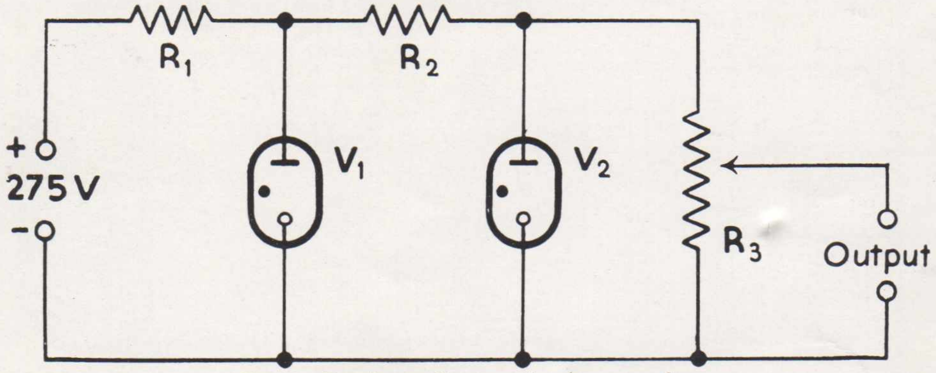


Fig. 1. Simple application of reference tube.

The 85A2 will draw a constant current of 6 milliamps while any voltage between 0 and 85 volts may be obtained from the potentiometer R_3. Negligible current should be drawn from R_3.

The Mullard reference tube type 85A2 offers an extraordinarily high level of burning voltage stability which is apparent both from the published data and from the typical graph of burning voltage stability against life which was published in Vol. 1, No. 2 of the "Outlook," March-April, 1958, page 13.

As will be seen the stability of the tube improves with increased operating time.

At the beginning of life the burning voltage rises at an average rate of 0.8% per 1,000 hours and this rise continues for about 300 hours.

The burning voltage then begins to fall but at a steadily decreasing rate. Thus after 1,300 hours the change of burning voltage is below 0.1% per 1,000 hours.

There are certain applications in which this latter order of life stability is required and it well repays the user to "age" the tube at a constant current of 6 milliamps.

However, in many industrial applications a very high order of operating stability is required over a relatively short period, say an eight hour day. Normally the equipment can be "zero set" at these intervals, or alternatively a very small long term drift is acceptable.

The graph of Fig. 2 shows the eight hour stability of a typical 85A2 after an ageing period of only 100 hours at 6 milliamps. It will be seen that the burning voltage variation is considerably less than 0.01%.

Because of the extremely low temperature coefficient of the 85A2 no stringent precautions are necessary to achieve this high order of stability. Provided the tube is shielded from draughts and not placed too close to any equipment with a changing heat dissipation, temperature fluctuations of a few degrees are tolerable. This compares very favourably with the conditions required for any other reference source offering comparable stability.

Referring again to the eight hour stability curve it will be noticed that the only appreciable changes in burning voltage occur during the first four minutes after switching on. Three minutes of this time cover the normal warming up period, and after this the actual change in burning voltage is only 5 millivolts.

LIMITING VALUES (Absolute Ratings)

Min. voltage necessary for ignition	115	V
Max. burning current	10	mA
Min. burning current	1	mA
Ambient temperature limits	—55 to +90	°C

PREFERRED OPERATING CONDITION

Burning current	6	mA

CHARACTERISTICS At Preferred Operating Condition

Max. ignition voltage	115	V
Burning voltage (variation from tube to tube)	83 to 87	V
Incremental resistance		
Average	300	Ω
Maximum	450	Ω
Temperature coefficient of burning voltage	—4.0	mV/°C
*Max. percentage variation of burning voltage		
During the first 300 hours of life	0.3	%
During the subsequent 1,000 hours	0.2	%
Max. short-term (100 hours max.) variation of burning voltage after the first 300 hours of life	0.1	%
Typical percentage drift of burning voltage per 1,000 hours after 1,300 hours	0.1	%

** After the initial warming-up period of 3 minutes.*

OPERATING NOTES

1. To obtain a good life a reverse current must not be drawn from this tube. This condition is satisfied if any inverse voltage does not exceed 75 V.

2. The maximum ignition voltage quoted is the greatest voltage which is necessary to ignite any tube in the presence of some ambient illumination. A voltage of at least this value must be available if reliability of ignition is to be obtained. In complete darkness there may be some delay in igniting the tube.

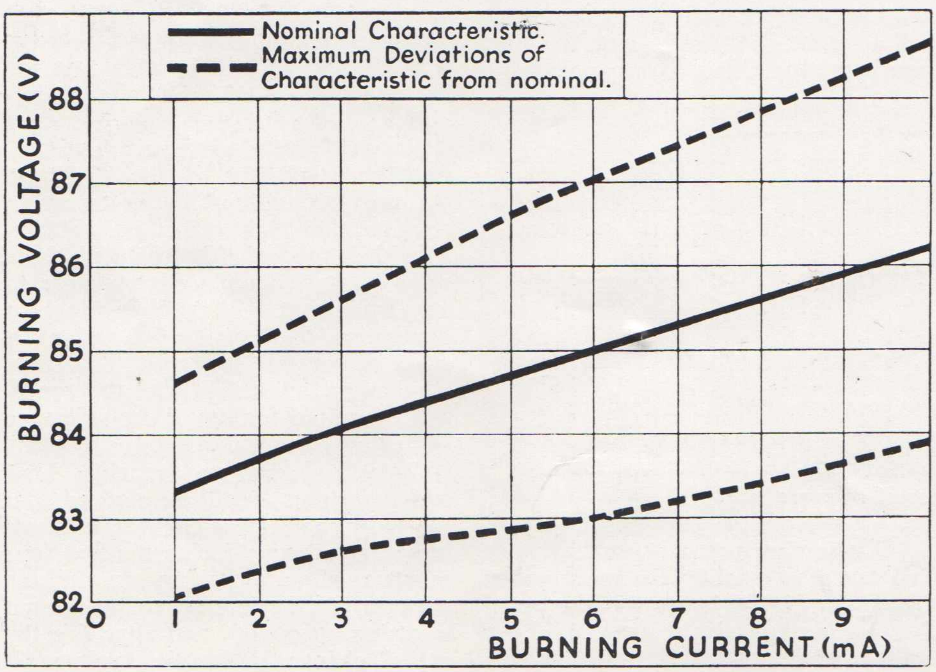
3. A steady burning voltage is reached within 3 minutes.

4. The greatest constancy of burning voltage is obtained if the tube is operated at only one value of current.

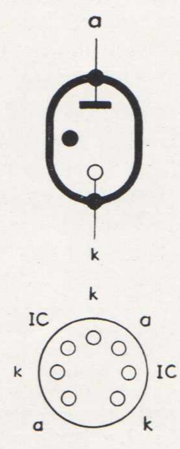
5. The noise generated by the tube over a frequency band of 30 to 10,000 c/s is of the order of 60μV, which is equivalent to the noise generated by a resistor of approximately 22 MΩ at a temperature of 300°K. The noise is evenly distributed over the frequency range.

DIMENSIONS

Maximum diameter 19 mm. Maximum seated height 47 mm.



Burning voltage plotted against burning current.



B7G BASE

IC: Internally connected. Make no external connections to these pins.

INPUT MIXING AMPLIFIER

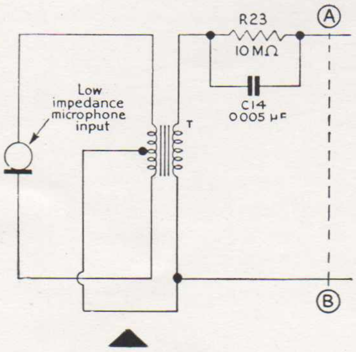


Fig. 2—Alternative Microphone Input Stage for Low Impedance Microphone.

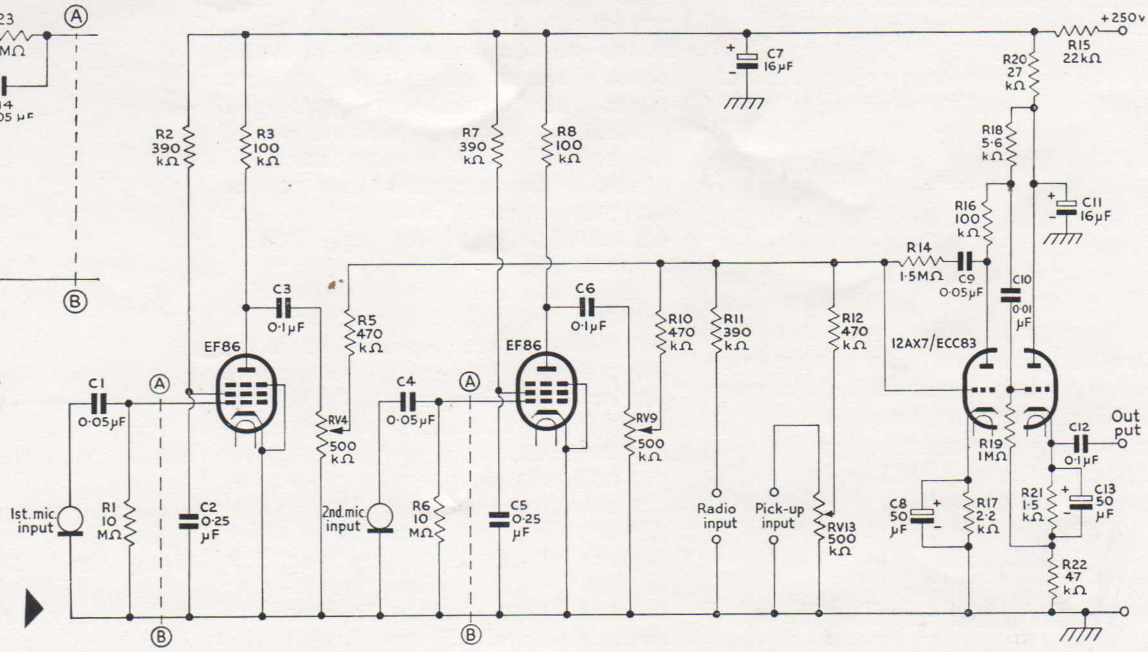


Fig. 1—Circuit of Four-Channel Input-Mixing Amplifier.

It may often be desirable to use several signal sources with an amplifier which only has provision for one input signal. The circuit described here is capable of handling four input signals and of supplying a mixed output suitable for a single-input amplifier. Two of the input channels of the mixer are suitable for microphone signals, a third is for radio or equalised tape input, and a fourth is for pick-up signals.

The circuit has been designed for use with the Mullard 'Five-Ten' amplifier in which the tone-control network has been disconnected, but it is suitable for any amplifier not requiring an input of more than 43mV for full output. It can be adapted quite easily, however, to give sufficient drive for the tone controls of an amplifier to be incorporated. With a simple modification to the output stage, the mixer will provide an output of about 800mV.

CIRCUIT DESCRIPTION

Both microphone stages in Fig. 1 are identical. Each is equipped with an EF86 operating with grid current bias obtained by means of the high-value grid resistor R1. The internal impedance of a crystal microphone is high, and consequently large losses in output will occur at bass frequencies unless R1 is also high. Hence the value of 10MΩ has been chosen for the grid resistor.

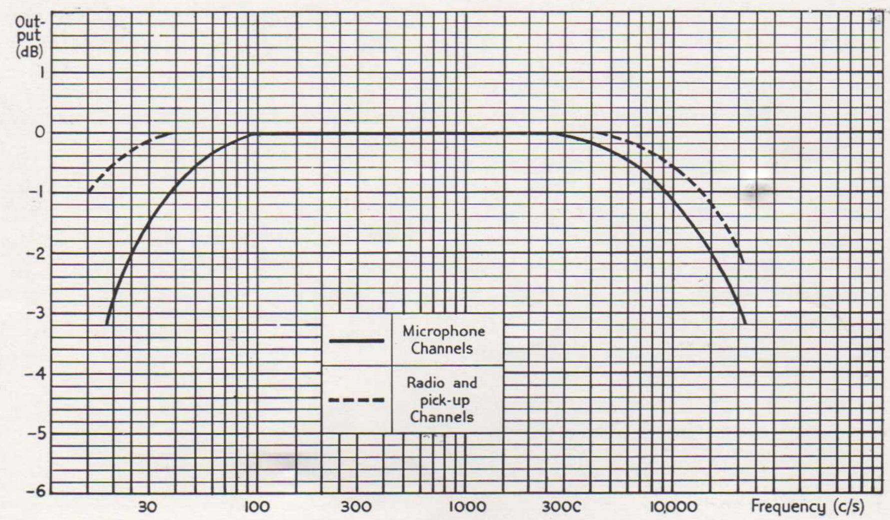


Fig. 3—Frequency Response Curves of the Amplifier.

The circuit can be adapted for a low-impedance microphone by using a step-up transformer in the grid circuit of the EF86. This arrangement is shown in Fig. 2, the connections A-B replacing those similarly marked in Fig. 1.

The output from each microphone input stage is R C coupled to the grid of one-half of a 12AX7/ECC83 double triode. The radio and pick-up input stages are also connected to this grid by way of R11, R12 and RV13. This half of the ECC83 is arranged as a voltage amplifying stage.

The potentiometers RV4, RV9 and RV13 serve for adjusting the signal levels in the microphone and pick-up channels; adjustment for the radio channel will be achieved with the gain control of the receiver used to feed the signal to the radio input terminals. The values of R5, R10, R11 and R12 are such that, with the potentiometers, there will be no interaction between channels. And, of course, they will prevent a short circuit if any potentiometer is set to a minimum.

Feedback is taken from the anode to the grid of the first half of the 12AX7/ECC83 by way of R14 and

C9. This provides a low impedance at the grid and minimises the loss in high frequency response due to Miller effect between anode and grid.

The output of the unit is obtained from the second half of the 12AX7/ECC83 which has been connected as a cathode follower. This connection provides a low output impedance which, in Fig. 1, is about 600Ω. Because of this, no treble attenuation will occur in consequence of cable capacitances if a long cable is required between the mixer and the main amplifier. However, although the internal resistance of the cathode follower is low, the input impedance of the main amplifier must be greater than 250kΩ to ensure that bass frequencies are not attenuated.

PERFORMANCE

The maximum output of the circuit of Fig. 1 is 43mV. This is obtained with a signal voltage of 3mV at either microphone input, 230mV at the radio input, or 250mV at the pick-up input. If greater output is required to drive an amplifier incorporating a tone-control network, this can be obtained simply by adjusting the coupling between the anode of the first half of the double triode and the grid of the second half. If C10 is joined directly to the first anode, an output of 810mV will be available. Intermediate values of output can be obtained by altering the values of R16 and R18. If, for example, these resistors are each 47kΩ, the output will be about 400mV.

In order to obtain the low output impedance of the cathode follower (12AX7/ECC83) the necessary attenuation of the signal is obtained by a split anode load R16, R18 in the first half of the double triode.

The response of either microphone channel is flat to within ± 3dB (relative to the level at 1kc/s) for a frequency range of from 20 to 20,000 c/s. The response of the other channels (which do not include an EF86 stage) is flat to within 2dB from 15 to 20,000 c/s. The response curves are given in Fig. 3.

The hum and noise level of the mixer unit is 50dB below the full output of 10 watts of the Mullard 'Five-Ten' amplifier for which the unit was designed.

VALVE PHASE-SPLITTERS

Many, but not all, push-pull output stages require some form of valve phase inverter or splitter to drive them. The advantages of push-pull operation are (i) a high power output is provided (ii) the cancellation of second order harmonics goes part of the way towards securing the low distortion required for high quality reproduction.

If the aim is chiefly to realise high output power, Class B operation can be used. The out-of-phase signals for the two control grids in such circuits can be obtained from opposite ends of a coupling transformer with a centre-tapped secondary.

For lower distortion than can be obtained from a Class B circuit, Class AB or A operation is used and a high degree of negative feed-back is applied. A coupling transformer is no longer suitable because it introduces phase shifts which may lead to instability with feedback. Also, a wider and flatter response can be obtained with purely R C elements. Some form of valve phase splitter is therefore required for high quality audio amplifiers.

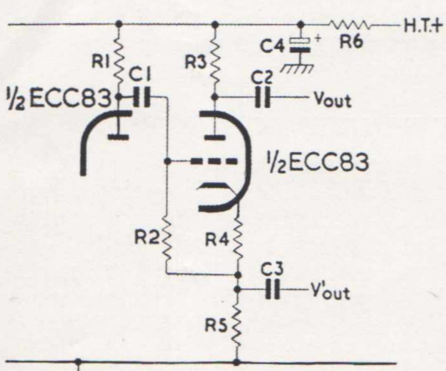


FIG. 1

The three basic types of valve phase splitter are shown in Figs. 1, 2 and 3. The first is the cathode follower and its action can easily be understood. The h.t. current flows in both the cathode and anode circuits and the flow of electrons through the valve makes the cathode go positive as the anode goes negative. If the anode load R3 is made approximately equal to the 'cathode load' R5, and this value is one or two times the anode impedance r_a of the valve, then a positive pulse on the cathode accompanies a negative pulse on the anode which is of the same size. Hence V_{out} and V^1_{out} are 180° out of phase and of equal amplitude.

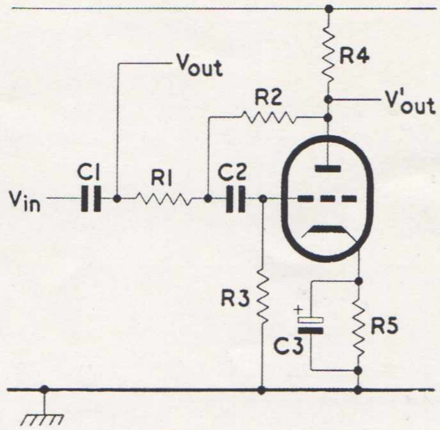


FIG. 2

The load line must be computed using the total load R3+R4+R5, where R4 is the bias resistor. Because R5 is unbypassed, there is a certain amount of negative current feedback which reduces the distortion. For the two outputs to remain equal at higher frequencies, the grid resistor R2 should have the highest preferred value permitted by the valve data, and the smoothing capacitance C4 should be high, at least 8μF. Unbalance at high frequencies is to some extent influenced by the valve capacitances, and the valve chosen should have an anode to grid capacitance virtually the same as the grid to cathode capacitance. The gain of the cathode follower type circuit is usually about 0.9, and the input impedance for usual circuit values can be taken as about 10 times the grid resistance shunted by a capacitance of about twice the anode to grid capacitance. The output impedance at the cathode end is much lower than the anode impedance r_a and at the anode end is much higher than r_a. The 12AX7/ECC83 is suitable for

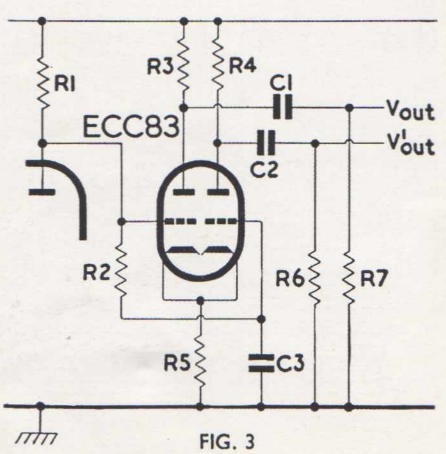


FIG. 3

this type of circuit; the first section operates as a normal voltage amplifier, and the other half is the phase splitter. This valve can withstand a heater to cathode voltage of 180V.

One application of the cathode follower is shown in Fig. 5. The first EF86 is a normal voltage amplifier, the second is the cathode follower. The two EF86's are operated for high gain under 'starvation conditions', so named because the high load resistances give low anode voltages and currents.

The second circuit to be considered is properly speaking a phase reverser (Fig. 2) rather than a phase splitter. It has been given various names, such as anode follower, see-saw and paraphase. One input for the push-pull output stage is taken straight from the coupling capacitor C1 from the preceding voltage amplifier. The input to the phase reverser is taken from a potential divider R1 R2 connected between the two output voltages, their values being such that the gain of the stage is unity ($V'_{out}/V_{in}=1$). When V_{out} is going positive, the grid is going positive, and the anode is going negative so that V'_{out} and V_{out} are 180° out of phase as required.

This circuit is not so widely used in audio amplifiers since there can be an unbalanced component because of the coupling capacitances. The values in the potential divider will depend on the maximum grid resistance permitted for the output valves. The circuit has the advantage of not requiring a voltage between heater and cathode, so that it is suitable for a double valve where the other half is required for some other purpose.

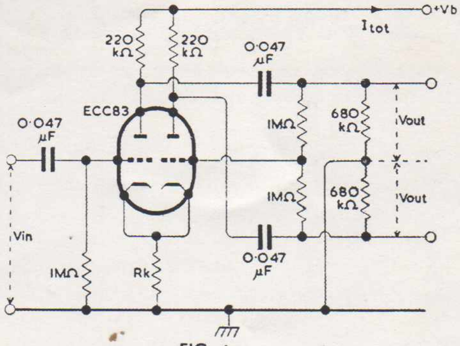


FIG. 4

Fig. 4 shows the 12AX7/ECC83 in a phase reverser circuit, the first section being a normal voltage amplifier and the second the phase reverser. The performance of the 12AX7/ECC83 in this circuit is given in Table 1.

The third circuit (Fig. 3) is of most interest as it is used in the '5-10' and the EL34 20-watt amplifier circuits. It is a cathode coupled phase splitter of the Schmitt type. A negative pulse on the input grid produces a positive pulse on the first anode, so that V_{out} is going positive. The second cathode, which is strapped to the first, goes negative at the same time. In the second section, the negative pulse on the cathode is equivalent to a positive pulse on the grid, and hence V'_{out} is going negative and is 180° out of phase with V_{out}. The grid of the second section is capacitively earthed by C3 for cathode input, and R2 ensures correct d.c. conditions in the second section.

The input grid of the Schmitt circuit is directly coupled to the anode of the preceding valve, and hence some 70 to 80 volts d.c. is applied to it. The bias for the valve is obtained by the voltage drop across the common cathode resistor R5, and the direct voltage on the cathode is therefore high. The cathode currents of both sections flow through R5, the d.c. components being additive, and the a.c. components in opposition.

For there to be some a.c. signal remaining on the cathode to inject into the second section, the two sections must not operate into exactly equal loads and grid resistors in the following stages. The anode load R4 of the earthed second section should be slightly higher than R3 for perfect balance. The high amplification factor (μ) of 100 for the 12AX7/ECC83 makes the difference only a few per cent, and even so a reasonable balance is maintained when R3 and R4 are equal. Optimum results are obtained when R4 is larger than R3 by 3%. In practice the two resistors should be matched to within 5% and the larger used for R4; the unbalance then cannot exceed 2%. The grid resistors R6

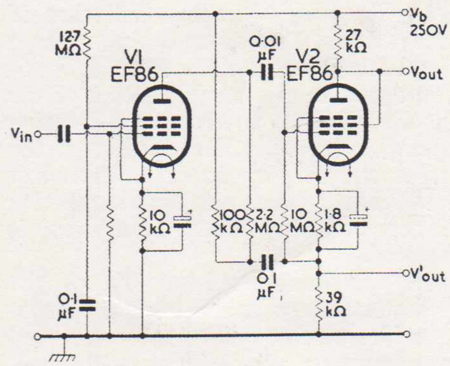


FIG. 5

and R7 for the output valves must be of close tolerance (±5%) as they form part of the anode load to the phase splitter. The frequency at which low frequency unbalance occurs depends on the timeconstant C3 R2; this timeconstant can be made long enough to maintain adequate balance down to low audible frequencies. High frequency balance is largely deter-

TABLE 1

V_b (V)	I_{tot} (mA)	R_k (Ω)	V_{out}* (V_{rms})	$\frac{V_{out}}{V_{in}}$	D_{tot}* (%)
250	1.08	1200	35	58	5.5
250	1.08	1200	7	58	1.1
350	1.7	820	45	62	3.5
350	1.7	820	9	62	0.7

* Output voltage and distortion at the start of positive grid current. At lower output voltage the distortion is approximately proportional to the voltage.

TABLE 2

V_b (V)	†V_a (approx.) (V)	I_a+I_a' (mA)	R_k (kΩ)	R_a (kΩ)	V_{out}* (V_{rms})	$\frac{V_{out}}{V_{in}}$	D_{tot}* (%)
250	65	1.0	68	100	20	25	1.8
250	65	1.0	68	100	7	25	0.6
350	90	1.2	82	150	35	27	1.8
350	90	1.2	82	150	10	27	0.5

* Output voltage and distortion at the start of positive grid current. At lower output voltage the distortion is approximately proportional to the voltage.

† V_a should be adjusted so that $I_a+I_a' = 1$ mA at $V_b = 250$V and 1.2 mA at $V_b = 350$ V.

mined by the layout of the wiring which can make the shunt capacitances unequal. The interelectrode capacitances of the 12AX7/ECC83 are sufficiently small and equal between the two sections for their shunting effect on the circuit to give negligible unbalance at high frequencies.

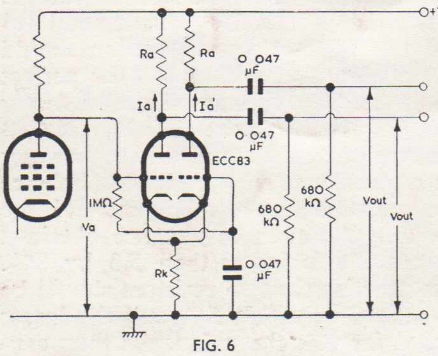


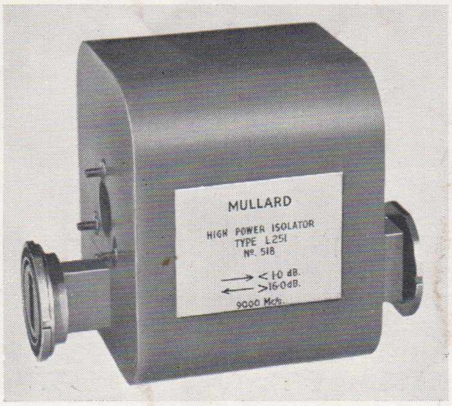
FIG. 6

The effective voltage gain ($V_{out}/V_{in} = V'_{out}/V_{in}$) is about half that of one section used as a normal voltage amplifier. Nevertheless there is sufficient gain in this stage because of the 12AX7/ECC83's high amplification factor (μ) of 100. The absence of the input coupling capacitor reduces low frequency phase shift and makes for better stability when feed-back is applied.

If the anode voltage V_a of the preceding stage is too high the negative bias on the splitter is too low and overdrive on peak signals will result in grid current distortion. Alternatively if V_a is too low the phase splitter bias will be too high and the valve will operate away from the linear part of the dynamic characteristic, again with increased distortion.

Table 2 shows the performance of a 12AX7/ECC83 operated in a cathode coupled Schmitt phase splitter (Fig. 6) under conditions rather different from those used in the '5-10' and the 20-watt 6CA7/EL34 amplifier.

X - BAND HIGH POWER ISOLATOR



The X-band high power isolator type L.251 is a non-reciprocal wave-guide component having an insertion loss in the direction of propagation of less than 1.0 dB and a reverse loss of greater than 20dB. The device is similar in principle to the low power isolator and depends for its action on the non-reciprocity exhibited by ferrite materials at microwave frequencies. This property is due to the effect of gyromagnetic resonance.

In the high power isolator two rectangular bars of ferrite are placed in a section of waveguide, surrounding which is a permanent magnet assembly. This serves to produce a transverse magnetic field in the ferrite material. By the suitable positioning of the ferrite and adjustment of the magnetic field, the non-reciprocal absorption properties of the ferrites are adjusted to an optimum so that a high reverse attenuation is achieved with a minimum attenuation in the forward direction.

The high power isolator is capable of absorbing up to 150 watts of power without loss of performance. The absorbed power is mainly that reflected by the impedance mismatch in the system and therefore the device may handle relatively high powers in the forward direction. For example, the isolator may be used in the signal path of a 300 kW peak, low duty cycle pulsed, radar transmitter.

Accessories

The high power isolator is suitable for use in standard X-band circuits, and special waveguide bends and mechanical fixing arrangements may be made available to specifications.

TECHNICAL SUMMARY
Electrical

Forward loss	Less than 1.0 dB over the band 8250—9750 Mc/s.	**Bandwidth**	The bandwidth is such that over the range 8250—9750 Mc/s the reverse loss is greater than 15 dB while the forward loss remains less than 1.0 dB.
Centre frequency reverse loss	Greater than 20 dB.		
Centre frequency	9000 Mc/s.	**Input VSWR**	Better than 0.9.

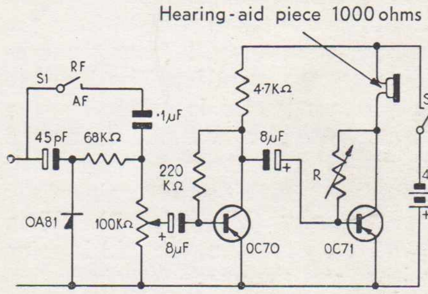
AMATEUR EXPERIMENTERS COLUMN

SIGNAL TRACER

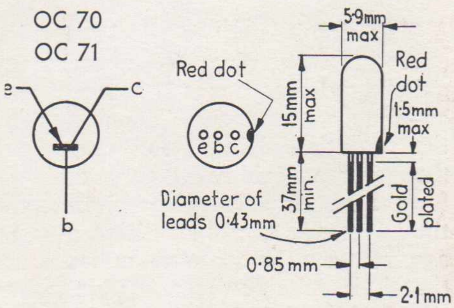
The signal tracer described is essentially a two-transistor amplifier. It may be found useful as an aid to fault location in radio receivers, television sets, R.F. and A.F. amplifiers.

An R.F. signal, for instance, may be followed from the aerial to the detector and by closing S1, right through to the output stage of a receiver.

A minimum number of components is used thus enabling the construction of an inexpensive and compact unit.



Adjust R for 3mA Ic



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MULLARD OUTLOOK

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