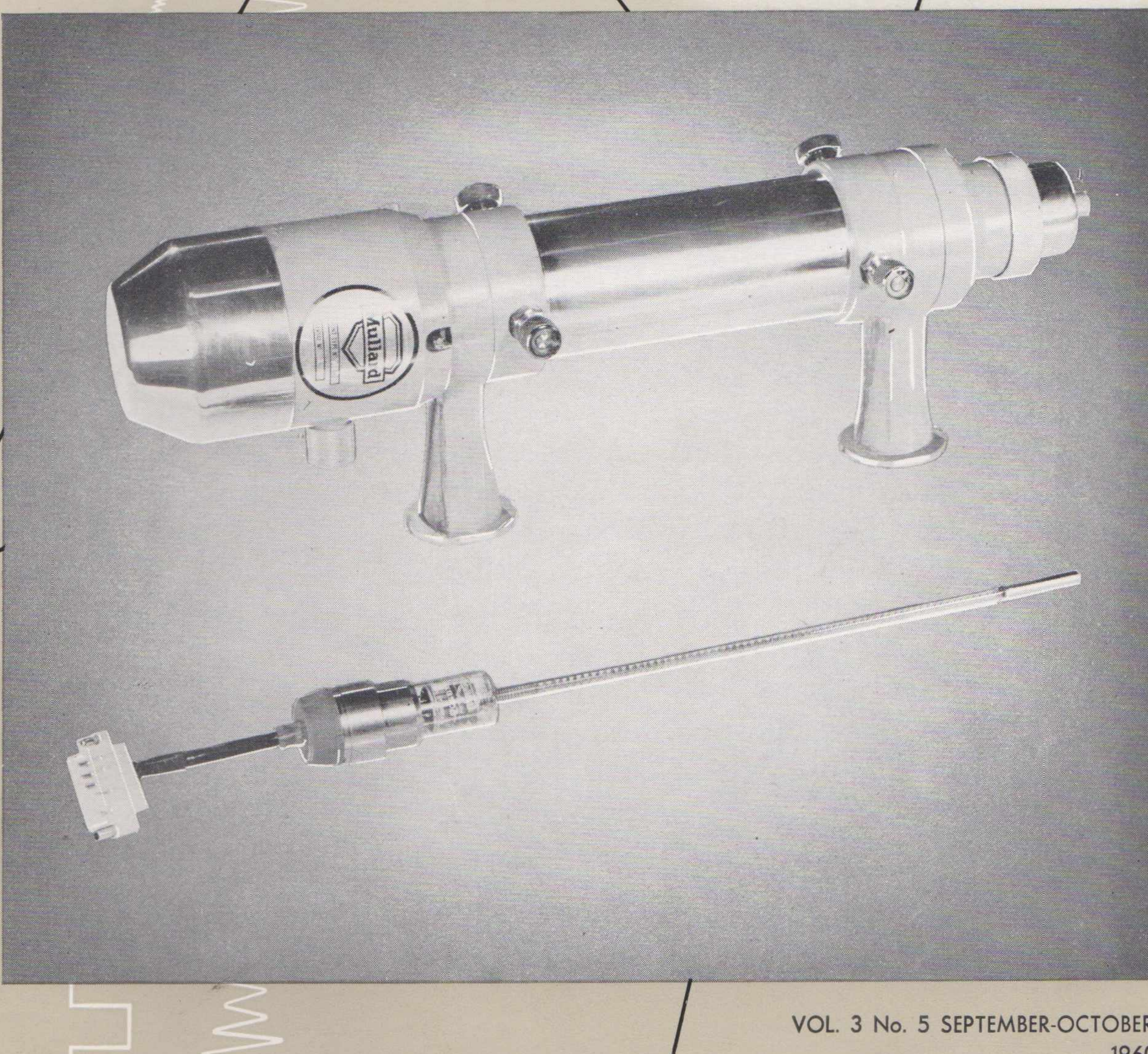
# Mullard Outlook

## Australian Edition



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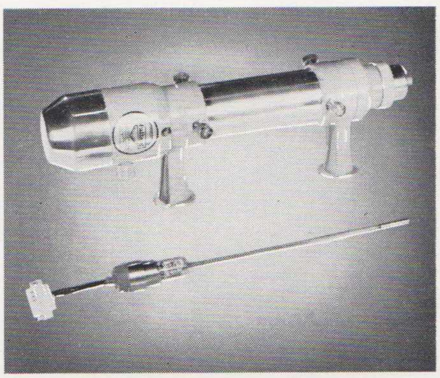

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## "For Services Rendered"

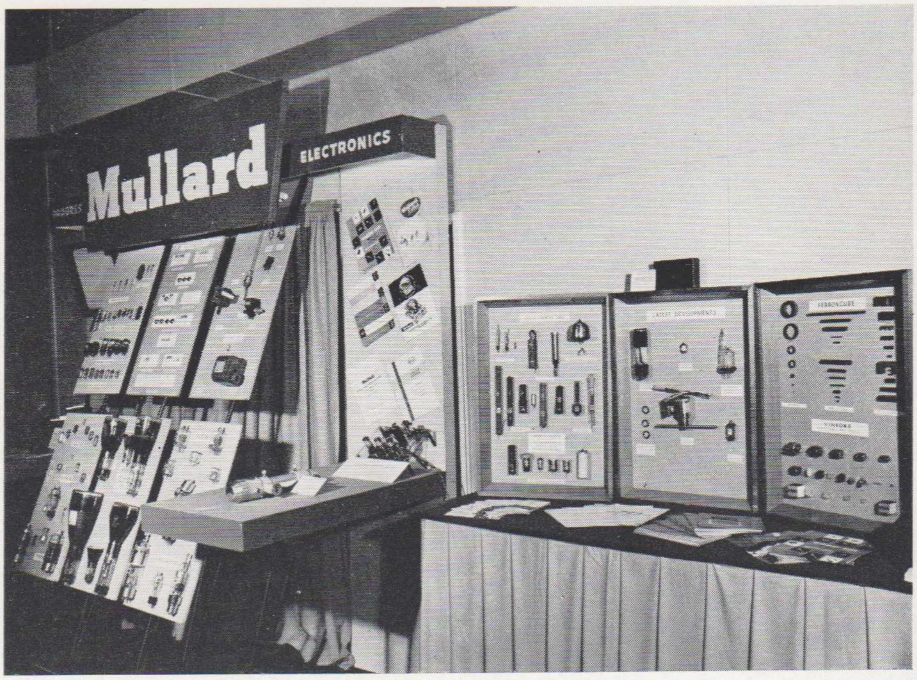
These words strike a note of gallant charm and, by custom, serve as an acknowledgment of Services that may have been commissioned in the first instance or as an appreciation of some extra service willingly given.

Some professions make a habit when charging for their services — the result of their experience and special training — of treating it very much as a highly commercial proposition — no more, no less — but where sincerity abounds it is fair value and an exchange of trust and goodwill.

We read much of the charges for TV service — components used, direct labour, indirect labour, travelling time, waiting time and so on — but hear little of the other factors behind the scenes, perhaps the result of inadequate public relations. For these are the attributes of real Service, the basic courtesies of trust and goodwill, the pride and satisfaction of rounding off a good job and the imbuing of a client with this enthusiasm. Only then can the charges be genuinely "for services rendered", whether a lone operator with a local pitch and a thousand TV receivers to maintain or whether a highly organized multiple.

# VIEWPOINT WITH MULLARD

## EXHIBITION OF SCIENTIFIC INSTRUMENTS




The seventh Exhibition of Scientific Instruments and Apparatus arranged by the Institute of Physics was held in the new Chemistry School, University of Sydney, from August 16 to 19.

The Mullard display included a selection of valves, electron tubes, semiconductors, microwave devices and specialised products from the comprehensive range already available to industrial, professional and research organizations together with a number of new developments, from the Mullard Research Laboratories, which are not as yet in production.

The microwave devices shown included a travelling wave tube complete with focussing assembly, Ferrite isolators for X-band and S-band, magnetrons, klystrons and disc seal valves.

Some interesting developments in the semiconductor field included a high frequency transistor for computer logic circuits with pulse repetition frequencies up to 10 Mc/s; a core driver transistor for ferrite memory systems which gives 750 mA pulses with exceptionally fast rise times and a low noise transistor for 100 Mc/s amplification in VHF communications equipment.

The already comprehensive range of Mullard ferroxcube includes square hysteresis loop components, completely assembled matrix planes and stacks for use as magnetic stores in digital computers as well as rods, tubes, rings, E-I-U cores and pot cores. A new concept in ferroxcube adjustable pot cores, Mullard Vinkors with cores having diameters of 18 — 21 — 25 — 30 and 35 mm for use at frequencies up to 200 kc/s, were shown and new types extending the range to 2 Mc/s will be available shortly.

Devices for ultra high vacuum techniques included ionisation gauges suitable for measurements down to $10^{-10}$ mm of mercury or use as ion pumps at $5 \times 10^{-11}$ mm; bakeable metal vacuum taps for use at temperatures up to 600° C at pressures of $10^{-9}$ mm of mercury and sealing rings which are self-compensating in the temperature range minus 83° C to plus 450° C and with leakage rates of $10^{-16}$ litres/sec. even after repeated baking.

A number of new Geiger-Muller tubes were exhibited for the first time in Australia and interest centred on an anti-coincidence arrangement comprising an end window tube surrounded by a guard counter which facilitates the design of equipment for low background counting techniques with a minimum of shielding.

The Mullard Technical Service Department is always pleased to offer assistance to equipment designers and users and the scope of our laboratory activities can be gauged from the various working exhibits showing valves, tubes and so on in operation. A three-stage decade counter employing Z302C tubes which do not require interstage amplifiers could be seen in conjunction with the recently introduced ORP90 cadmium sulphide photo-conductive cell which provides sufficient output, even with a small light input, to operate a relay directly without amplification. Having highest response in the near infra-red region the ORP90 is ideal for such applications as industrial counting, smoke monitoring, warning and safety devices, etc.

A continuously variable A.C. power supply capable of supplying up to 25 amperes, employing two thyratrons in inverse parallel connection remotely controlled by ganged 1 watt potentiometers, was also demonstrated.

During the exhibition technical films from the Mullard Film Library were screened and created considerable interest — these films are available on loan from our Film Service and enquiries are always welcomed.

## MULLARD-AUSTRALIA PERSONALITIES

Mr. A. S. Tollow joined the Company in 1951 and is now responsible for the initiation of mechanical design and construction of test equipment for both our Applications Laboratory and Valve and Tube Service Centres.

With a keen interest in high quality music reproduction, Mr. Tollow is well versed in audio technology ranging from pre-amplifier layout requirements to enclosure construction techniques.

A versatile craftsman whose vocations range from structural welding to sub-miniature electronics, Mr. Tollow's hobbies of electronics and photography often find expression nowadays in the production of printed circuit boards for electronic assemblies developed in our Applications Laboratory.

# HIGH FREQUENCY TRANSISTORS

Ever since the first introduction of transistors, there has been a demand for semiconductor devices to operate at higher and higher frequencies. One of the most important recent advances in transistor technology is the alloy-diffusion technique used by Mullard. This technique provides transistors having uniform high-frequency characteristics and, just as important, makes possible large-scale production of transistors at economical prices.

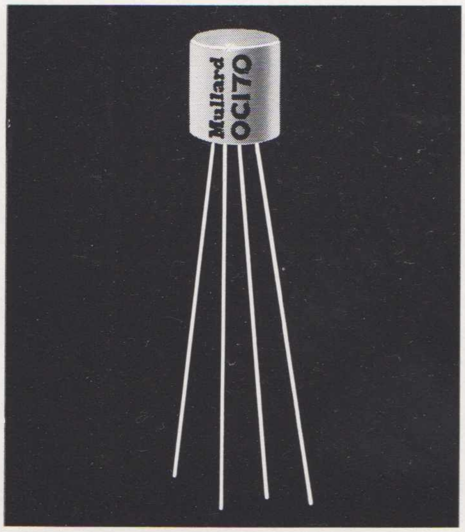
**Why use the technique?**

Of course there must be good reasons why this technique is superior to previous techniques used for high-frequency transistors. The OC42, which has an average cut-off frequency of 15Mc/s, probably represents the upper limit of frequency obtainable in quantity production using the normal germanium alloying technique. One reason for this is that any spreads in the thickness of the germanium wafer directly affect the width of the base of the finished transistor. This phenomenon appears fundamental to a device alloyed from both sides of the crystal. The base width, and also the depth of the junction, of the finished transistor depends on the area of the germanium wetted by the indium pellet and also on the tolerance of pellet size.

When alloying the transistor it is possible for the emitter and collector to melt right through, thus short circuiting the base. It is therefore necessary to aim at a mean base thickness large enough to prevent a high rejection rate from this cause.

However the alloy-diffusion technique can be controlled much more accurately and, even in large-scale production, a base thickness of only a few microns is possible. Short-circuiting of the base is almost entirely eliminated because work is carried out on one side of the wafer only.

With this very thin base, a low base resistance is obtainable. The thickness of the base is the main factor which limits the cut-off frequency. Theoretically, cut-off frequencies of several hundred or even




*Radio frequency germanium alloy diffused transistor type OC170. This transistor has a typical cut-off frequency of 70 Mc/s, and a current amplification factor of 100 at 1 kc/s.*

perhaps a thousand megacycles per second are possible.

**What the technique is**

The alloy diffused transistor is built up on a wafer of p-type germanium, which is later used as the collector. Fig. 1a is a diagrammatic representation of the constituents before the heating process. Two metal pellets, one (B) for the base and the other (E) for the emitter, are placed close together on one side of the wafer. Pellet B contains only n-type impurities, while pellet E contains both n and p types. When this assembly is heated to an appropriate temperature in a gaseous atmosphere, germanium dissolves into the metal pellets until saturation is reached. If the temperature is maintained, the impurities in pellets B and E diffuse into the germanium wafer.

The p-type impurities in pellet E diffuse very slowly and they penetrate only a negligible distance into the wafer. The n-type impurities in both pellets (B and E) have a high rate of diffusion and so penetrate further into the wafer and form an n-type layer. Since diffusion also takes place via the gaseous atmosphere, this layer extends to the exposed surface of the germanium between the two pellets (see Fig. 1b).

The diffused n-layer forms the base which, by specialised manufacturing techniques, can be limited to a thickness of 5 microns (one two-hundredth of a millimetre). The concentration of impurities in this layer is graduated between the emitter and collector junctions, and it is this gradient which produces the 'accelerating' field (Fig. 2).

Whilst the assembly is cooling, a layer of germanium recrystallises from the pellets just as it would in normal alloy techniques. The recrystallised layer beneath pellet E is predomin-

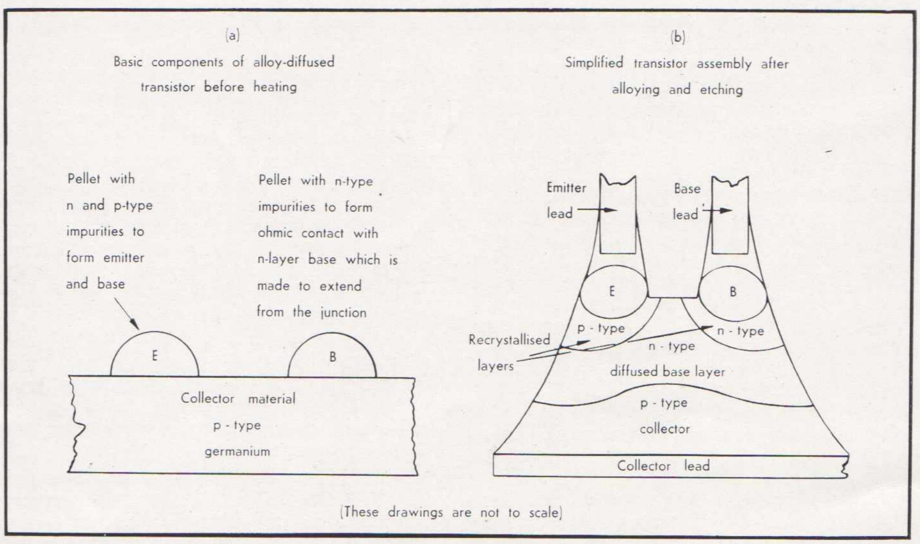



*Fig. 1—Two stages in the alloy-diffusion process.*

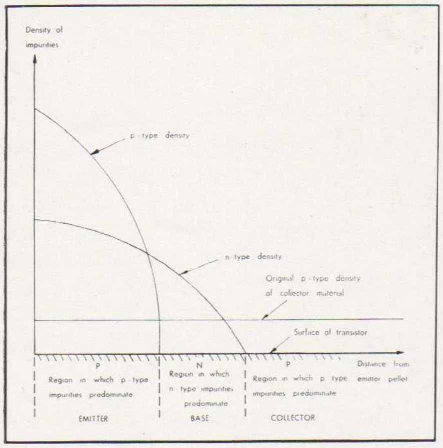



*Fig. 2—Distribution of impurities through the transistor assembly, showing the graded concentration which produces the drift or 'accelerating' field in the base.*

antly p-type because the p-type used is more soluble in recrystallised germanium than the n-type impurity present. The p-type material forms a p-n-p junction with the diffused n-type layer and the original p-type collector wafer. The recrystallised layer under B is n-type, and forms an n-n (non-rectifying) junction with the n-type base layer, which extends from the p-n-p junction between emitter and collector. Pellet B is thus used for making the ohmic contact to the extremely thin base.

After etching away this base layer where it is not either part of the junction or it does not form the ohmic contact with the base pellet, the assembly is ready for final processing and encapsulation.

**The first in our range**

Some months ago the first two transistors in our alloy-diffused range were supplied, mainly for use in specialised industrial equipment. These transistors were the OC170 and OC171, which service engineers and dealers may encounter in sets in the near future. The cut-off frequencies are 70 and 100Mc/s respectively. Subsequent transistors being developed in this range demonstrate the great potentialities of the technique: fast-acting transistors for various functions in computers: p-n-p-n four terminal transistors applicable in telephone exchanges: and still higher frequency R F transistors. All can be produced in quantity, reliably and economically to the customer.

# HANDY-PACK


Illustrated above is the Handy-Pack a recent addition to the Mullard Service for the assistance of the wholesaler, retailer and service engineer. Whilst the Handy-Pack is of assistance to the wholesaler for his stock shelves, undoubtedly its greatest advantage will be seen in the service department where it will not only facilitate stock control but will provide, for the engineer, a compact unit of storage for Mullard valve types.

The revised Handy-Pack comes in two sizes which will carry the majority of the range of Mullard Entertainment Valves. This streamlining into two sizes will assist to solve your storage problem.

# HIGH POWER AUDIO VALVES AND RECTIFIERS

In addition to the well-known 'World Series' of audio valves for domestic amplifiers and record players, Mullard have a range of high-power valves suitable for all types of relay and public-address systems. The following list includes types available for maintenance purposes. It shows the power output available from two valves in push-pull.

**Triodes**

| | |
|---|---|
| MY3-275: | 1.3kW at 3.0kV, class B. |
| MZ2-200: | 1.2kW at 2.25kV, class AB2. |
| TY2-125: | 700W at 2.5kV, class B. |
| TY3-250: | 1.34kW at 3.0kV, class B. |
| TY6-5000A: | 13.3kW at 6.0kV, class B. Forced air cooled. |
| TY7-6000A: | 20kW at 7.0kV, class B. Forced air cooled. |

**Tetrodes**

| | |
|---|---|
| QV06-20: | 90W at 600V, class AB2. |
| QV08-100: | 300W at 750V, class B. |
| QY4-250: | 1.24kW at 3.0kV, class B. |
| QY4-400: | 1.75kW at 4.0kV, class AB. |

**Mercury**

| | |
|---|---|
| RG1-240A: | 500mA at 2.0kV (bi-phase). |
| | 500mA at 4.0kV (bridge). |
| RG3-250: | 500mA at 3.1kV (bi-phase). |
| | 500mA at 6.3kV (bridge). |
| RG3-1250: | 2.5A at 4.0kV (bi-phase). |
| | 2.5A at 8.2kV (bridge). |

**Inert Gas**

| | |
|---|---|
| RR3-250: | 500mA at 3.1kV (bi-phase). |
| | 1.0A at 1.5kV (bi-phase). |
| | 500mA at 6.3kV (bridge). |
| | 1.0A at 3.0kV (bridge). |
| RR3-1250: | 2.5A at 3.1kV (bi-phase). |
| | 2.5A at 6.3kV (bridge). |

# ON BEHALF OF THE ELECTRONIC VALVE

D. S. SIMKINS, P.ENG.

**Since many electronic valve failures are due to causes other than valve defects, the important factors in valve selection and application are examined, with particular attention to temperature ratings and variation of characteristics during valve life. Special quality valves are defined, and recommendations made to equipment designers and end-users.**

No doubt there are those among us who say "thank goodness for semi-conductors, now we can get rid of valves!" One reason for coming to this somewhat premature conclusion could be an unfortunate past experience with valves. Is it a fact that they are as bad as some people paint them, or in our quest for "what's new" have we failed to familiarize ourselves with what we have? Undoubtedly some of the troubles experienced with valves are of our own making, since about 50% are through misapplication and 50% through the incorrect choice of the valve itself.

It should be recognised that a valve can only fail for one of two reasons, namely:

a) that it is a good valve operated outside its design parameters, or
b) that it has been fairly treated, and the valve is not up to its specifications.

In the former case it is an application engineering problem, and in the latter a valve manufacturing problem. We should become more aware of why valves fail, not the mere fact that they do.

What then may we expect from the hot cathode oxide coated types? Firstly we need to determine accurately what our needs are, as a valve manufacturer, equipment designer, or equipment end-user. It is no use asking for rugged valves when we really want reliable valves. The three categories of main use are:

a) Entertainment functions requiring valves adequate for the job but built down to a price, where failure is a matter of low replacement cost and inconvenience at worst.

b) Military applications which may call for very stringent limits on certain parameters — parameters which are not important in other applications. Price is not necessarily a first consideration, but correct functioning is.

c) Sandwiched between these two markets is the very wide and important professional valve field comprising all types of communications and industrial control. Price and function are both important considerations. First cost is not the only monetary factor involved. Failure of equipment due to valve failures can produce high secondary costs when production lines are halted or in the case of some communications equipment human life is endangered.

### Special quality valve classifications

A galaxy of terms is used to describe valves having some desirable properties over and above the general run of entertainment types.

Historically the **rugged** valve was the first major attempt by the valve industry to do something about the mechanical weakness in the valves which were then used in aircraft equipment. No attempt was made to control electrical characteristics.

The **reliable** valve, however, was the result of efforts to limit both electrical and mechanical failures with a view to achieving a higher probability of reliability in a given equipment.

A **rugged** valve is therefore one whose rate of failure for mechanical reasons is low but whose rate of failure due to electrical defects is no different from the standard product. A **reliable** valve is one for which certain claims are made concerning the probability of the tube continuing to operate satisfactorily under stated conditions.

The rugged valve only has any real advantage in conditions where vibration and shock may be encountered, such as in mobile and aircraft equipment. Where an equipment maker or user requires to improve valve reliability (and consequently equipment reliability) in equipment that is not subject to vibration and shock he should ensure that the valves are "reliable" and not just "rugged."

There are many terms used to describe either of these types of valve such as "Premium quality," "Special quality," "Professional," "Plus," etc.

Valves which come into the category of "Special quality" are reliable valves as defined above, and most types are rugged also. The features built into the valves are such that life, under correct operating conditions, will exceed 10,000 hours.

### Mechanical advances

Figure 1 illustrates one of the important improvements in mechanical structure that have been incorporated in rugged valves. The drawings show the old (a) and the new (b) designs of mica spacers. The new form has no fragile pieces around its perimeter and therefore is not so likely to flake or chip.

Normally the inside diameter of the valve envelope is parallel and a close fit on the serrated mica spacer. In the new design the envelope is somewhat larger in diameter than the mica spacers, and is constricted onto the top spacer after the electrode assembly has been inserted.

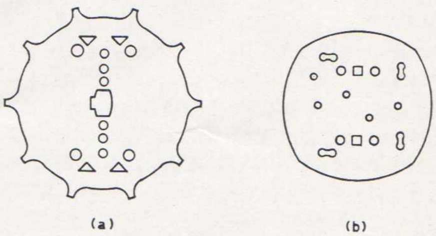
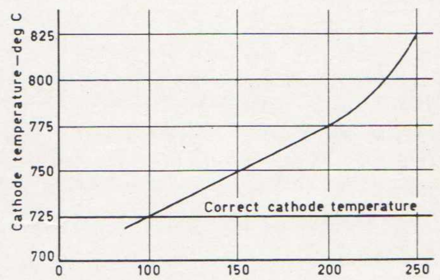
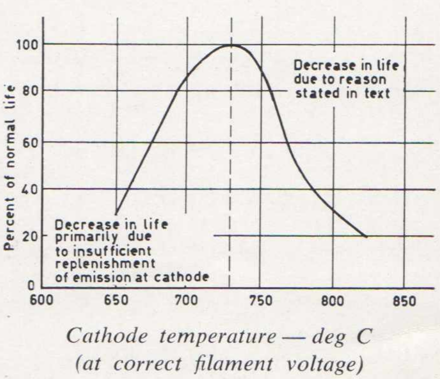



FIG. 1




*Bulb temperature — deg C*

FIG. 2




*Cathode temperature — deg C (at correct filament voltage)*

FIG. 3

This is a very advantageous method of construction since the assembly is in no way distorted until it has arrived at its final position. This is very important in valves whose characteristics are critically dependent on geometry. Most deterioration due to vibration shows up when there is some initial movement which may be made worse; where no initial movement is possible, deterioration does not normally result.

**Cathode temperature important**

The nominal cathode temperature is about 725°C at the correct filament voltage. This temperature is far more critical than is generally realised. Variations of plus 10% can produce cathode temperatures around 780°C that cause rapid deterioration of cathode life down to about 40% of the possible. Ten percent under-running reduces the cathode temperature by an approximately equal amount and cathode emission demands must be proportionally reduced if cathode damage is not to result.

Cathode temperature and therefore valve life is also affected by the bulb temperature, irrespective of the contribution to cathode heat that the filament makes. Fig. 2 shows the effect of bulb temperature on cathode temperature in a typical oxide coated miniature valve. This leads to Fig. 3 which shows the effect of cathode temperature on life. Two typical examples are as follows:

a) At 100°C bulb temperature and at correct filament voltage the cathode temperature is correct at 725°C. If the bulb temperature increases to 200°C (not uncommon in much industrial equipment), the cathode temperature increases to 770°C. From Fig. 3 it can be seen that this reduces the normal average life to 60%. These conditions combined with a filament over-voltage of 10% would reduce the life to approximately 35%.

b) At a bulb temperature of 250°C the cathode temperature would be 820°C, reducing the life to 20% of normal average. These conditions combined with a 10% increase in filament voltage would reduce life to only a few hours.

The obvious result therefore of excessive bulb temperature is greatly reduced life, and this is brought about primarily by:

a) Increase in cathode temperature.

b) Release of gas from glass or other electrodes which damages the cathode by positive ion bombardment.

c) Vaporisation of the getter deposit which redeposits on colder surfaces and causes leakages between electrodes.

d) Positive ion current flow in grid 1 as a result of gas, which reduces the bias voltage and may cause over-dissipation if $R_{g1}$ is high.

Another detrimental factor arising from elevated cathode temperature is the phenomenon known as "inter-face." Inter-face, also known as "sleeping sickness," is the development with time of a resistance between the cathode coating and the sleeve onto which the coating is deposited. The rate at which this occurs is dependent on the cathode temperature and the amount of work that the cathode has to do. It therefore shows up more rapidly in valves which are operating on stand-by operation than in those which are not. Valves designed for this type of operation should be used if possible. If such valves are not available it is advisable to use types of sufficient capacity to meet the current requirements when derated to give a lower cathode temperature.

Recommendations resulting from these considerations are:

a) The filament voltage should be kept within ±5% of the correct value.

b) The bulb temperature should preferably be around 125°C although good lives can be had up to 160°C. It is important that bulb temperatures be measured under the exact conditions in which the valve is intended to be run, that is with valve shields in place and the unit with its case on and in its final location. The modern method, using temperature paint, is quite simple and reliable. There is a very good proprietary brand on the market known as "Tempilaq."

c) There are specialist manufacturers who provide suitable shields that will reduce bulb temperature. The increased cost of a better shield may appear unwarranted, but if it saves the cost of even one valve it will probably more than compensate for its higher initial cost, let alone the cost of interruption of service.

Other factors can produce bad running conditions which affect the life of the valve. This is particularly true of multi-element communication types where the mode of operation requires the control grid as well as the screen grid to run positive. Typical valves are QV1-150A, QV05-25, QQV02-6, QQV03-10, QQV03-20A, QQV04-15, QV06-20, QQV06-40A, QQV07-40.

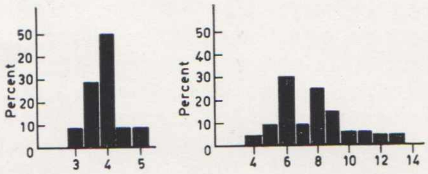
In the published dynamic performance figures for any valve typical operating conditions are normally shown for frequency multipliers and power amplifiers, both modulated and unmodulated. Certain parameters are fixed, and other parameters result from these conditions. The independent parameters, over which we have control, are plate voltage, screen voltage, grid 1 voltage, and plate current. The parameters over which we have no direct control are grid 2 current and grid 1 current.

The manufacturer does not stipulate how the grid 1 and grid 2 voltages shall be derived, leaving the equipment designer free to achieve the necessary figures under the most economical commercial conditions. In valves employing tungsten and thoriated emitters, the differential between the plate and screen voltage is usually fairly large, and a separate grid 2 supply is usual. However, in oxide coated emitters, where more emission is available, and lower supply voltages result, the grid 2 voltage is normally derived by using a dropping resistor, and the D.C. bias obtained by self-rectification of the incoming signal through the grid leak.

With fixed values of $R_{g1}$ and $R_{g2}$ it follows that only one value of grid 1 current, and one value of grid 2 current, can represent the correct voltage figures. This in turn requires that every valve, both during its life and from valve to valve, has identical current divisions.

To supply valves having identical current divisions would mean very small productivity and consequently enhanced valve costs. In practice, the current division does vary from valve to valve, and from batch to batch. These variations of grid 1 and grid 2 current may not be ignored, and should be compensated for by a change of $R_{g1}$ and $R_{g2}$. This will give the constant values of $V_{g1}$ and $V_{g2}$ that are necessary to preserve constant input power, efficiency and output. To determine the spread of values of $R_{g1}$ and $R_{g2}$ for a given valve type it is first necessary to obtain from the manufacturer the spread of $I_{g1}$ and $I_{g2}$ that may be expected under a typical set of dynamic operating conditions (see Figures 4 and 5).

Both $R_{g1}$ and $R_{g2}$ may be infinitely variable or a tapped series chain, whichever is more compatible with the commercial design. Only by following this procedure is it possible to get constant output over wide ranges of valves. The alignment procedure should be that at the point of maximum output the grid 2 voltage should read as prescribed, and the plate current with a fixed amount of rf drive should be adjusted by means of $R_{g1}$ to a constant figure.




*Figs. 4 and 5. Graphs showing the spreads in control grid ($I_{g1}$) and screen-grid current ($I_{g2}$), measured on a batch of 6252 double tetrodes at a frequency of 150 Mc/s. The valves were adjusted to a plate voltage of 500V., a screen-grid voltage of 200V., and a grid bias of —60V. The plate current was 100mA. The currents measured are plotted horizontally and the percentage of tubes showing each current vertically.*

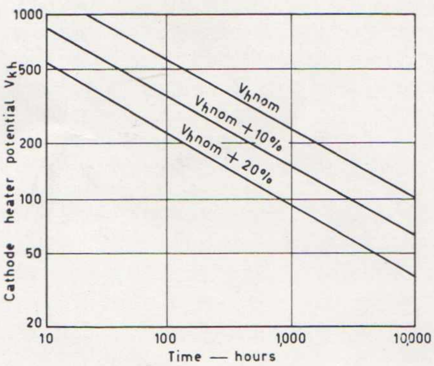



FIG. 6

**Cathode to filament voltage**

Figure 6 shows the relationship between $V_{kf}$ (filament positive) and the time in which 1% of a batch of valves develop filament-cathode shorts, with the filament voltage as parameter. The values are for guidance only, having been obtained by extrapolation of accelerated tests carried out at higher voltages and temperatures. It can be clearly seen how the life of a valve is shortened by raising $V_{kf}$ and how this is influenced by the filament voltage. It can be seen that $V_{kf}$ should not exceed 100V if a life of 10,000 hours is required.

## RECOMMENDATIONS

Specific recommendations based on the factors outlined above can be made to both the designers and end-users of professional equipment. These are listed below.

**Designers**

1. Ascertain at the time of your initial considerations the specific end-of-life characteristics of the valve. This information can be supplied by the manufacturer — a typical example is shown in Table 1. If the valve selected is available from more than one manufacturer, a correlation between the different brands should be made. After all, your customer is the party eventually faced with the replacement problem; you only have it as a transitory problem.

| Parameter | Typical values | End-of-life values |
|---|---|---|
| Plate current $I_a$, mA | 3.0 ± 0.5 | less than 2.0 |
| Screen-grid current $I_{g2}$, mA | 0.65 ± 0.2 | „ „ 0.35 |
| Mutual conductance S, mA/V | 1.85 ± 0.35 | „ „ 1.2 |
| Negative grid current $-I_{g1}$, μA | 0.1 max. | at least 0.2 |

*Table 1. Typical and end-of-life characteristics of pentode type 6084.*

2. If your requirements are for long periods of stand-by, consider valves designed specifically for this mode of operation or request recommendations for larger derated valves.

3. Find out the spread of the dependent parameters such as grid 1 and grid 2 currents, particularly when circuits are designed with fixed parameters such as dropping resistors and grid leaks. Without this knowledge only difficulty can result from the purchase by the end-user of valves from several sources, whose parameters differ widely in this regard.

4. Keep the minimum value of grid resistance in all cases. When your requirements call for valves of the electrometer variety, discuss these with the valve manufacturers first. Some very good valves are available in this category.

5. Seriously consider a reduction in the number of types in a given equipment, even if this gives slightly less than optimum performance per stage. This improves the over-all situation in terms of inventory costs, productivity due to volume, availability, uniformity, and cost.

6. Alternate valve line-ups should be offered to the customer, who will then have the choice of paying the difference in cost between special quality and standard valves.

7. Application engineering information and help is available from the valve manufacturer and should be sought.

**END-USERS**

1. When buying new equipment the initial price and specification are the apparent factors involved. It is advisable to make sure from your own or consulted engineering services whether the conditions of use in your particular location (vibration, temperature, hydro voltage, etc.) are such that the equipment will fully meet your reliability requirements. If the conclusion is that this is not so your equipment supplier should be requested to tender for equipments which take these factors into account. This will save money in the long run.

2. It may not be assumed that all valves bearing the same type number are made equally well by different manufacturers. The real cost in valve replacement (not taking into account second order costs due to lost time and break-down) is the cost per life hour. Find out not only "how much," but also "how often," and in this way one can really determine "how little."

3. Many equipment suppliers are forced by competitive practices to ignore special quality valves, even though they would considerably enhance the quality of the equipment. This often leads to a low initial price but also to a high replacement cost. The valve manufacturer's application engineering services are aware of alternate solutions such as the use of voltage regulators. While they are not directly concerned with marketing these devices, they are usually familiar with the sources of supply, available types, application details, etc.

**Conclusions**

The electronic valve of today has reached a very highly specialised state of development and there are several classes of valves resulting from this. The Special Quality group of valves can be obtained with known initial characteristics and tolerances, known end-of-life characteristics and known mechanical features, subject to them being operated under conditions which can be clearly stipulated. These conditions are not unreasonable and minimum lives of 10,000 hours may be expected. When reviewing these statements against some of the current practices a big difference will be apparent.

The electronic valve is not an unreliable product under fair operating conditions — the Special Quality valve is no answer to abuse. Information is available from industry and in the interest of all concerned it should be sought.

# 3W TAPE AMPLIFIER CIRCUIT

## FOR MODERN TAPE DECKS

The original Mullard circuit for a self-contained tape amplifier (Type A) was first published in the Mullard booklet 'Circuits for Tape Recorders.' This circuit catered for the then popular tape speeds of 3¾ and 7½ in./sec., and treble equalisation was obtained by means of negative feedback taken through parallel-T networks situated between the anode and grid of the first section of the double triode type 12AX7/ECC83.

Later in 1959, a major modification to the circuit was published in Mullard 'Circuits for Audio Amplifiers.' Treble equalisation was provided by means of a resonant circuit incorporating a Ferroxcube pot-core inductor. Provision was also made for three tape speeds: 3¾, 7½ and 15 in./sec.

However, present day commercial tape decks now favour the three tape speeds: 1⅞, 3¾ and 7½ in./sec. Also, progress in the design and manufacture of record/playback heads and better quality tapes has greatly improved the high-frequency performance of these modern decks, and the treble boost provided in the earlier circuit may often be excessive. Consequently, further modifications have been made to the Mullard circuit, and details of the revised version are given in this article.

**CIRCUIT DESCRIPTION**

The revised circuit diagram of the self-contained tape amplifier is given in Fig. 1. The circuit for the power supply, which is constructed as a separate unit to reduce the possibility of hum in the amplifier, is given in Fig. 2.

A three-stage circuit is employed for both record and playback processes, with a fourth stage acting as the bias oscillator when recording, and the audio output stage during playback. The necessary switching between the recording and playback conditions is effected by a two-way, three-wafer switch SA. This switching can be divided into three groups:

(i) that required to connect the record playback head to the recording stage and bias oscillator during recording and to the input stage during playback.

(ii) that required to give treble equalisation during recording and bass equalisation during playback.

(iii) that required to connect the 6BQ5/EL84 as the bias oscillator during recording and as the audio output stage during playback.

Equalisation depends on the tape speed used, and facilities are provided at the switch SB for the three speeds 1⅞, 3¾ and 7½ in./sec. This switch must be set for the appropriate speed during recording and playback.

In the first stage of the circuit, the EF86 acts as a simple voltage amplifier to signals derived from microphone or radio inputs or from the playback head. Jack plugs and sockets are used for switching the inputs during recording so that only one of the inputs can be used at a time.

The second stage contains recording and playback equalisation. During recording, a resonant circuit incorporating a tuned Ferroxcube pot-core inductor L1 (Mullard type WF816) in the lower arm of an attenuator is used to provide treble boost. The frequency at which maximum treble boost occurs is determined by switching (at SB1) the tuning capacitor (C5, C6 or C7). The amount of treble boost is controlled by the resistors R7 and R12. The treble boost characteristics (Fig. 4) should give good results with most combinations of tape and record playback head, but if the boost is excessive, the inductor should be damped by connecting a resistor across each tuning capacitor. The optimum values for these resistors should be determined by listening tests.

The values of the resistors R9, R10 and R11 arranged at switch SB2 have been chosen to give the correct feed-

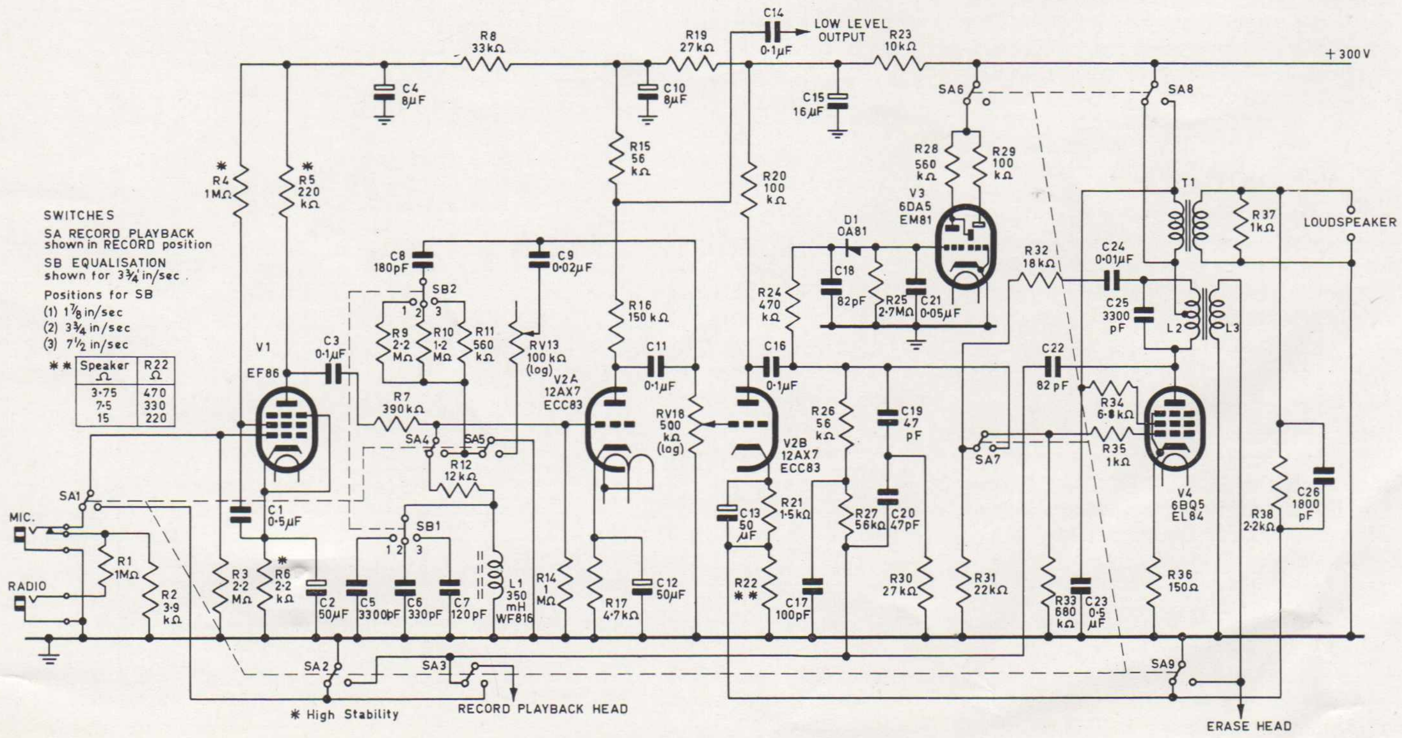



*Fig. 1—Circuit diagram for tape amplifier*

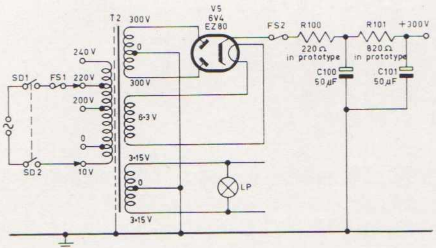



*Fig. 2—Power supply circuit*

back between the anode and grid of the first section of the 12AX7/ECC83 for bass equalisation during playback. The tone control RV13, C9 is operative only during playback, giving continuously variable treble cut.

A low-level output (56kΩ impedance), is taken from part of the anode load of this stage. It can be used for monitoring purposes while recording and for feeding an external amplifier during playback. The full output from the equalisation stage is fed via the volume control RV18 to the grid of the second section of the 12AX7/ECC83. This control is operative during recording and during playback (through the recording output stage). The recording signal is fed to the recording head by way of parallel-T network which is tuned to the bias frequency. This arrangement produces a substantially constant current drive to the head and at the same time provides efficient rejection of the bias voltage at the anode of the recording output stage.

Parallel bias injection is made to the recording head via C22, the value of which determines the bias current. Bias output is taken from the anode of the 6BQ5/EL84 connected in a Hartley-type oscillator circuit. The bias oscillator coil and the primary winding of the output transformer are arranged in series, the latter being short-circuited during recording. The presence of the capacitor C23 prevents the abrupt cessation of oscillation when the change-over switch is switched from record to playback, and this prevents the record/playback head from becoming permanently magnetised.

During playback, the erase head is earthed at SA9, and approximately 10dB of negative feedback is applied from the secondary winding of the output transformer to the cathode of the section of the 12AX7/ECC83. Distortion in the audio ouput stage amounts to 3% at 1kc/s for an output of 3W.

The 6DA5/EM81 signal level indicator is fed via an OA81 detector circuit from the anode of the recording output stage. The sensitivity of the indicator is set by the value of the resistor R29 in the target-anode circuit, and has been made high enough for a high value of series resistance R24 to be used to minimize the loading effects on the recording stage. Conditions are such that the target shadow closes for a recording current of 80μA.

The power supply is of a conventional form and uses a full-wave rectifier, type 6V4/EZ80, with a CR filter. The smoothed HT line voltage is 300V.

## PERFORMANCE

All performance figures given here apply for a combination of a Collaro 'Studio' tape deck and Scotch tape, 150.

## FREQUENCY RESPONSE

Treble boost is incorporated during recording and bass boost during playback. Separate equalisation is provided

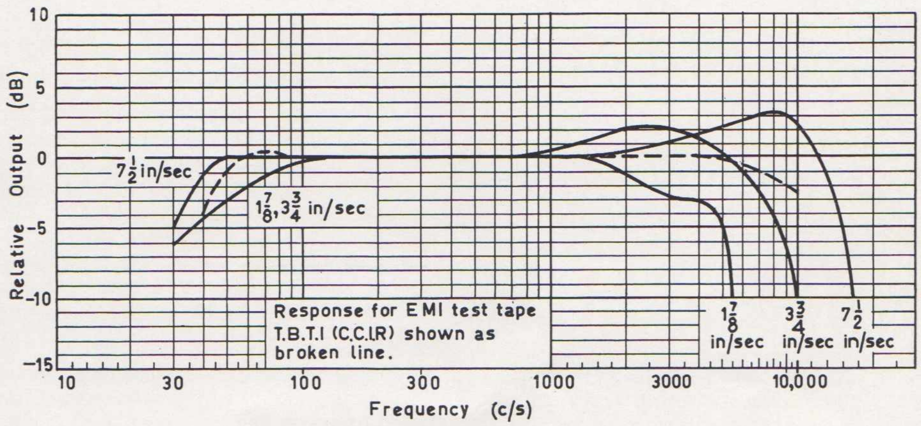



*Fig. 3—Frequency-response characteristics*

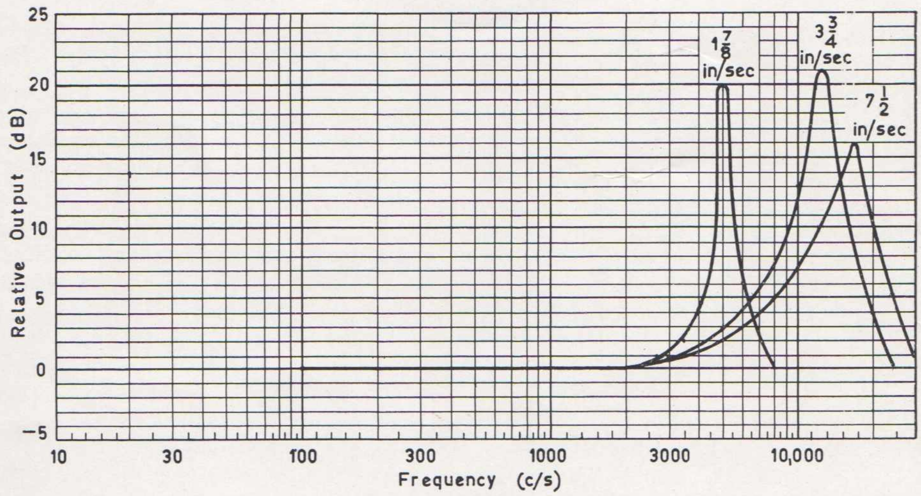



*Fig. 4—Treble-boost characteristics*

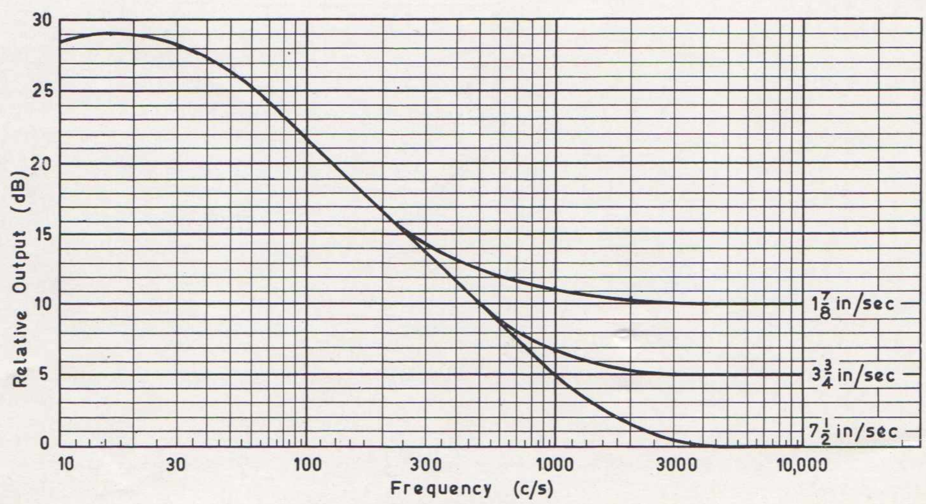



*Fig. 5—Bass-boost characteristics*

for tape speeds of 1⅞, 3¾ and 7½ in./sec. to give the overall frequency response characteristics reproduced in Fig. 3. It can be seen from Fig. 3 that the response is within ±4dB of the level at 1kc/s between the following frequencies:

| | |
|---|---|
| 1⅞ in./sec. | 40c/s to 5kc/s. |
| 3¾ in./sec. | 40c/s to 8kc/s. |
| 7½ in./sec. | 35c/s to 15kc/s. |

The response at the higher frequencies depends upon the type of tape and head and, to a lesser extent, upon the value of bias current. The values given above will normally be obtained with a bias current of approximately 0·9mA when using typical modern high-impedance heads and popular types of tape. The playback equalisation at 7½ in./sec. conforms to the C.C.I.R. characteristic and gives very good reproduction with pre-recorded tapes.

### RECORDING SENSITIVITY

The recording sensitivity measured at 1kc/s for the peak recording level of 80μA through the record/playback head or 9V at the anode of the second section of the 12AX7/ECC83 are as follows:

*Microphone*

| | |
|---|---|
| Input impedance: | 2·2MΩ |
| Sensitivity: | 1mV |

*Radio or Pick-up*

| | |
|---|---|
| Input impedance: | 680kΩ |
| Sensitivity: | 250mV |

The bias current is 0·9mA, the erase current is 115mA and the erase voltage is 25V.

Treble boost is applied during recording and the characteristics for the three tape speeds are shown in Fig. 4.

### PLAYBACK SENSITIVITY

The playback sensitivity measured at 5kc/s for an output power of 3W or a low-level output voltage of 250mV are as follows:

| | |
|---|---|
| 1⅞ in./sec.: | 1·3mV |
| 3½ in./sec.: | 2·4mV |
| 7½ in./sec.: | 4·5mV |

These values are adequate for most modern heads.

Bass boost is applied during playback and the characteristics for the three tape speeds are shown in Fig. 5.

### RECORDING-LEVEL INDICATOR

The 6DA5/EM81 indicator is set to 'close' at a sustained peak recording current of 80μA through the recording head. The indicator does not function during play-back, the HT supply being disconnected at the section SA6 of the record/playback switch, and this gives a positive indication of the position of the switch.

# SIMPLE VALVE MEASUREMENTS

*This article is the sixth in a series being published in Outlook dealing with experiments for the examination of the properties and behaviour of thermionic valves. These experiments include measurements from which the characteristic curves of various types of valves may be plotted.*

### TETRODE

The tetrode or screen-grid valve has two grids. The *control grid,* nearer the cathode, performs the same functions as the single grid of the triode. The second grid, usually termed the *screen grid,* is located between the control grid and the anode, and is maintained at a substantially constant positive potential usually a little lower than the anode potential at the working point. (See Fig. 11.)

The screen grid therefore exerts an accelerating force on the electrons emitted from the cathode, and because of its location, the screen grid is the major factor in determining the value of the cathode current, i.e., the total electron current drawn from the cathode *at a particular value of control grid voltage.*

The cathode current consists of two components:

1. The *anode current,* comprising those electrons which pass through the meshes of the screen grid and are collected by the anode.

2. The *screen grid current,* comprising the electrons which are intercepted by the screen grid.

### $I_a/V_a$ CHARACTERISTICS

The cathode current is divided between the anode and the screen in proportions depending upon the operating conditions. Figure 12 shows one $I_a/V_a$ curve for a tetrode, taken at control grid voltage ($V_{g1}$) = P and screen grid voltage ($V_{g2}$) = Q, together with a curve showing the variation of the screen grid current ($I_{g2}$) with variation of anode voltage, $V_{g1}$ and $V_{g2}$ remaining constant at P and Q respectively.

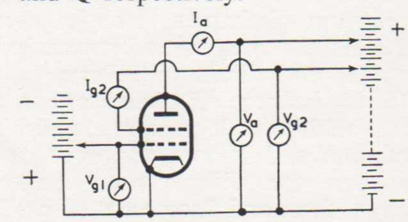



FIG. 11.—BASIC CONNECTIONS OF A TETRODE.

At $V_a = 0$, the whole of the cathode current flows to the screen grid, so that $I_{g2}$ is large and $I_a$ is zero, as might be expected. As $V_a$ increases, anode current commences to flow, and at first increases with increase of $V_a$, the increase of $I_a$ being accompanied by a corresponding decrease of $I_{g2}$.

Neglecting for the time being that part of the curves in the region B—C over which an increase in $V_a$ results in a *decrease* of $I_a$ (an explanation of this is given in the section headed The "Negative Resistance" kink in the $I_a/V_a$ Characteristic) it is seen that beyond the point D the screen grid current is but small, and that $I_a$ is large and almost independent of the anode voltage.

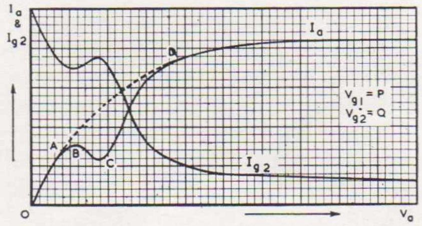



FIG. 12.—$I_a/V_a$ AND $I_{g2}/V_a$ CHARACTERISTICS OF A TETRODE.

This fact constitutes one of the main advantages of the screen-grid valve, for it means that the dynamic characteristic is a much closer approximation to the static characteristic than in the case of the triode.

### THE "NEGATIVE RESISTANCE" KINK IN THE $I_a/V_a$ CHARACTERISTIC

The reason for this apparently abnormal behaviour of a tetrode is that electrons reaching the anode at high velocity expel other electrons from the anode material. This phenomenon is termed "secondary emission." If the anode voltage is higher than the screen grid voltage, most if not all of these secondary electrons are attracted back to the anode; but if the anode voltage is less than the screen grid voltage, most of the secondary electrons flow from the anode to the screen grid. This counter-flow of electrons represents a nett reduction in anode current. Over the region A—B, therefore, the rate of increase of anode current is less than would be expected (see dotted line in Figure 12) while over the region B—C the increase of secondary emission is actually greater than the increase of primary electron current, and a decrease of nett anode current results.

In other words, in this region the valve behaves as if it possessed *negative resistance.* This region of the curve must be avoided in practical applications, and the operating range of the valve for stable performance is therefore restricted.

# FLUORESCENCE & GLOW DISCHARGE

From time to time home constructors have written expressing concern at the blue glow sometimes observed in power valves of the 6CA7/EL34 class. A typical reply is published below, since it is believed clarification on the topics of fluorescence and glow discharge would be of interest to our readers.

"The phenomena of fluorescence and glow discharge are two entirely separate entities which are sometimes confused by newcomers to the field of electronics.

The first phenomenon relates to the ability of certain chemical compounds to emit light when bombarded by fast particles, i.e., high speed electrons, Beta particles or so-called gamma (X) radiation. The effect is well-known and, indeed, the radiographer at the local hospital often uses the fluorescent screen to view the shadow image of various working organs of the human body. In this case the irradiating source is an X-ray tube producing radiation in the gamma range. Similarly, the humble television picture tube has a fluorescent screen which is excited by a narrow beam of high speed electrons.

In the normal radio valve, particularly the larger power audio output types, all of the electrons emitted from the cathode are not necessarily captured by the anode, screen grid, etc., and these stray electrons impinge upon the mica spacers and the inside walls of the glass envelope. Compounds such as magnesium oxides, aluminium oxides and their carbonates, etc., are deposited on the mica spacers and, by evaporation processes, a thin film of these compounds may become deposited on the inside walls of the glass envelope. If the valve is hard pumped, i.e., has a high vacuum, the possibility of these stray electrons colliding with a gas molecule, thereby losing a lot of their kinetic energy, is remote and so high velocity electrons strike the inner walls of the glass and on the mica spacers, which by design or accident are coated with a material having fluorescent properties. Fluorescence in an electronic valve is readily identified by virtue of:

a) its location either on the inside wall of the glass envelope or on the mica spacers, etc.;

b) its colour which is *bluish-green* (not purple); and

c) the fact that, since under signal conditions the stray electron pattern will change, the fluorescent pattern will also change in intensity and area as the valve is driven or as the operating conditions are changed.

The effect is in no way injurious to, nor inhibitive of, valve life. In fact it indicates a high degree of vacuum and the inference, if any, to be drawn from this would be contrary to the above statement.

Glow discharge is an entirely different phenomenon in that here electrons, by collision with gas molecules, lose their kinetic energy and cause ionisation of gas molecules, with the resultant discharge between two electrodes having a potential difference in excess of some 60V. This is the principle of all discharge valves, voltage regulating valves and the humble neon lamp.

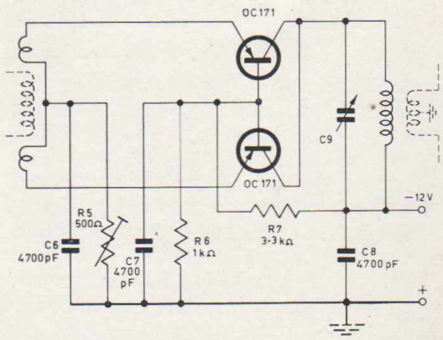
As you know, when the electrons in the outer shell of an ionised gas atom or molecule are excited, light of specific wavelength is produced which may be examined in a spectroscope and hence the particular gas identified. Such a technique is called "emissive line spectroscopy" and is the reason we know that the sun's chromosphere is a blanket of burning hydrogen and helium.

Returning to the more mundane, nitrogen — which comprises some 80% of our air — when ionised, yields a purple-violet glow and hence a "soft" valve will show a gas discharge colour of this wavelength. With variation of gas pressure this glow may either be confined to the proximity of the electrodes or fill the entire envelope space and should further information on this phenomenon be required any physics textbook describing Crookes' experiments on electric discharges through gases will yield the correlation between gas pressures and discharge volume.

Glow discharge effects are not as a rule variable with respect to drive conditions and in any case once one has seen the difference in colour between these and fluorescent effects it is easy to differentiate between them.

We trust this explanation will ease the doubts in your mind raised by the incidence of fluorescence in 6CA7/EL34 valves and reiterate that this phenomenon will not inhibit valve life, so you may look forward to many hours of musical enjoyment from your High Quality Amplifier."

# AMATEUR EXPERIMENTERS COLUMN




This transistor frequency multiplier is designed to be used in conjunction with the fifth overtone crystal oscillator featured in Outlook Volume 3, Number 4. The emitters are connected in push-pull, whilst the collectors are parallel-connected as in the well-known push-push doubler circuit. The efficiency of this type of doubler may approach that of a straight amplifier since there is a collector current pulse for each cycle of the output frequency. The emitter-tank-circuit is not tuned and merely consists of 2 turns 13 B & S silvered copper wire airwound to an inside diameter of ⅜″ and spaced so that 1 turn is positioned at each end of the crystal oscillator tuned circuit. The collector-tank-circuit is tuned to 144.4 Mc/s and consists of 2 turns 13 B & S silvered copper wire airwound to an inside diameter of ⅜″, spread over a length of ½″.

With the power connected, and the oscillator functioning correctly, the emitter resistor R5 and the collector-tank-circuit should be adjusted for maximum RF output, ensuring at all times that the maximum collector dissipation of 83mW, for each transistor, is not exceeded.

As the aerial coupling coil will vary, depending on the type of aerial used, 1 turn of 13 B & S silvered copper wire airwound to an inside diameter of ⅜", with the centre tap earthed, may be used as a starting point for a ½ wave dipole.

*In order to comply with the requirements of the Wireless & Television Act 1904 (as amended) equipment such as that described may only be operated in accordance with the relevant License as issued by the P.M.G.'s Department.*



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