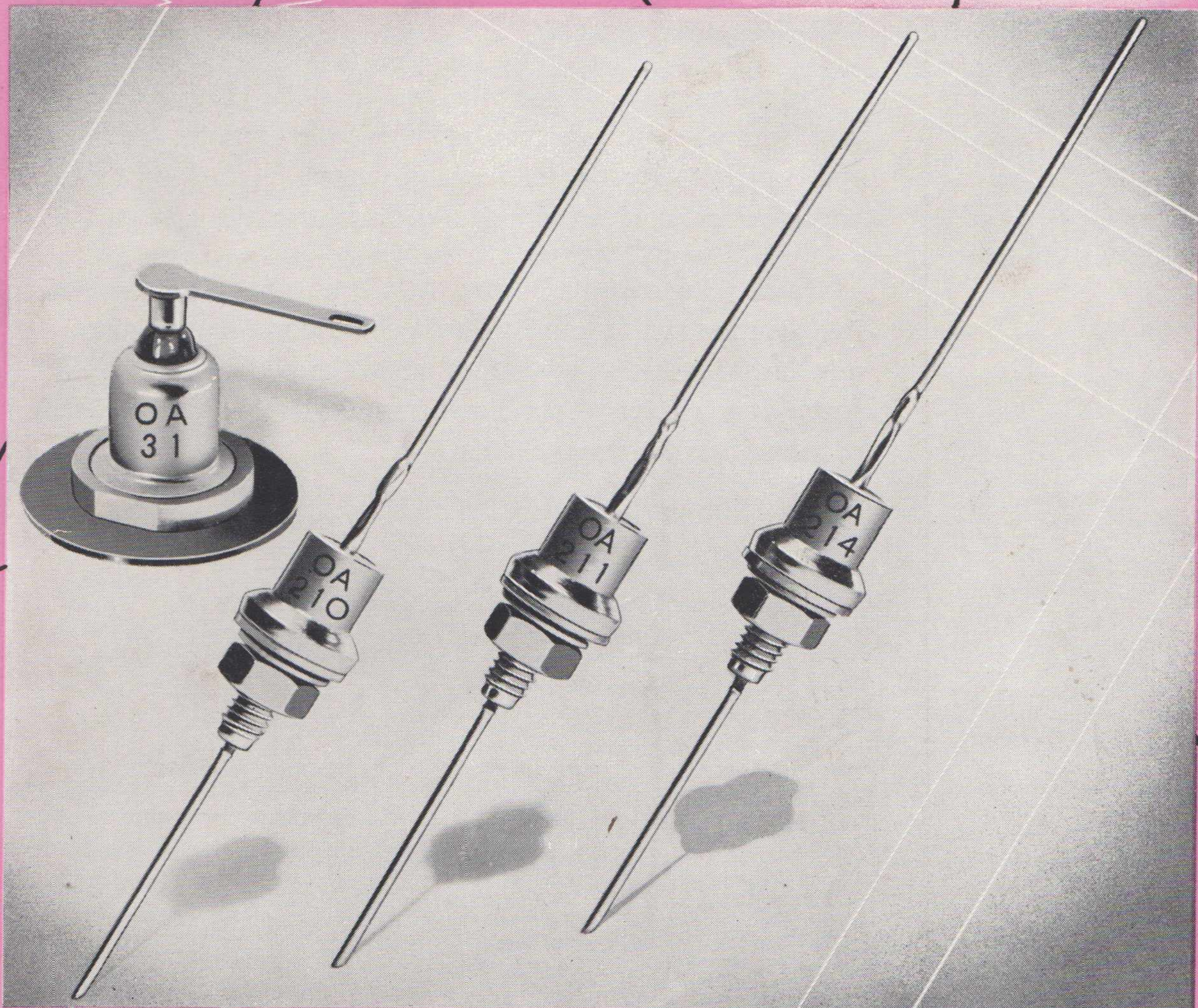
Mullard Outlook

Australian Edition



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1959

MULLARD - AUSTRALIA PTY. LTD.

VOL. 2 No. 6 NOVEMBER-DECEMBER, 1959

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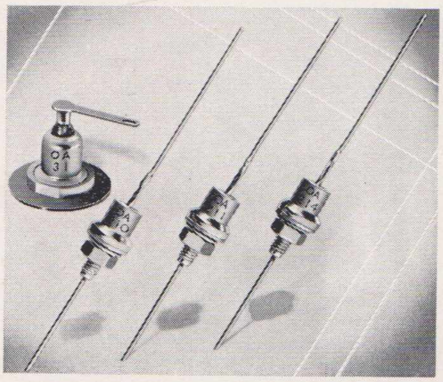

The OA31 Germanium Junction Diode in metal construction will supply up to 24 volts at 3.5 amps in a single phase half-wave rectifier circuit with resistive load. Also shown are the Silicon Power Rectifiers OA210, OA211 and OA214. Abridged data and application notes for the OA210 may be seen on page 70.

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To all our readers, both in Australia and overseas, we who produce the Outlook extend warmest greetings for Christmas and best wishes for a prosperous New Year.

The passage of time is one thing which humble mortals have so far been unable to accelerate or retard despite the phenomenal achievements of the past year in space vehicle technology and Einstein's relativistic prophecies dating back over two decades.

With these thoughts in mind we consider 1959 in retrospect and from your correspondence believe the Outlook is achieving our constant objective of keeping you up to date on technical and commercial developments in the electronics sphere.

On the international scene future advances in space technology may enable man to hold some control over time—an awe inspiring thought—but an achievement which may yield a better appreciation of our closeness to nature and the realisation of mankind's universal desire—

Peace on Earth and Goodwill Towards Men!

VIEWPOINT WITH MULLARD

MULLARD FILMS

This article is based on a recent Mullard Ltd., London press release and serves to indicate the widespread popularity and acceptance of Mullard Films by Educational Establishments.

During the year 1956 Mullard films were being viewed by a total annual audience of 150,000. In the three years which have elapsed since then this audience has grown to a figure exceeding 1,750,000 per annum excluding television audiences.

The major film-making Industries now include Mullard in their ranks and two major awards and numerous commendations have placed Mullard in a class comparable to any of these.

Mullard Film programmes cover a wide variety of subjects within the industrial range such as—

(a) Purely Educational;

(b) Educational Documentary;

(c) Industrial and Sales promotion; and finally,

(d) Industrial Technical.

Films catering for Advanced Science Students are—

Principles of Ultrasonics
The Linear Accelerator
Discharge through Gases
Principles of the Transistor
Vacuum Practice
Photo Emission

On a more general level, the History of Modern Science Series offer—

Mirror in the Sky
Conquest of the Atom

These films have been shown on television not only in the United Kingdom but in numerous other countries including the United States of America.

Other Mullard Films such as—

The Junction transistor in Radio Receivers
Made for Life
Manufacture of Radio Valves
Modern Magnetic Materials
Particles Count
Special Quality Valves
The Transistor—its principles and Equivalent Circuits
Ultrasonics

have also proved to be of interest to viewing audiences as may be seen from their record of screenings. The area of distribution of our films is now quite extensive and includes—

Schools, Technical Colleges, Universities and other educational establishments;

Government Departments including the G.P.O.;

Electricity Commission;

Radio and Electrical Manufacturers;

Manufacturers and users of industrial electronic equipment;

Radio, Electrical and other societies;

The Navy, the Army and the Air Force;

The Aircraft Industry and Airlines;

Miscellaneous Industrial Concerns;

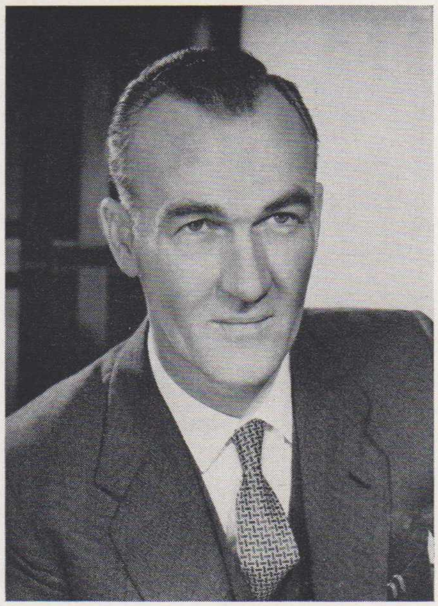
Television Companies;

Radio and Television dealers and service engineers.

The latest independent Mullard production is "From us to View", a film about TV Picture Tubes for which Mullard received the active co-operation of "Associated Rediffusion". The first part of this film shows the journey a television picture takes from the camera to the Studio Director monitoring the transmission—to the Master Controller and from thence to the transmitter and the viewer's home. From this stage the quality of the picture in the viewer's home will be largely dependent upon the performance of his television set and its all-important component—the television picture tube. The second half of the film shows some aspects of the extensive research, manufacturing and testing facilities that contribute to the high performance of Mullard Radiant Screen Television Picture Tubes.

Several other films are in the planning or early production stage. Some of these will be completed late next year, others will be introduced as supplementaries or alternatives and, as new films arrive in this country a brief synopsis will be published.

MULLARD-AUSTRALIA PERSONALITIES



With this issue we have pleasure in introducing Mr. Henry King who is in charge of the Mullard Valve and Tube Sales and Service Centre at Trafalgar Street, Petersham.

Mr. King has been with the Company for a number of years, during which time he has specialised in the statistical analysis of valve and picture tube life. During this time he has been vitally concerned with the development and construction of specialised test equipment for this purpose.

A background of four years' war-time service in the R.A.A.F., followed by ten years with the Postmaster - General's Department enables him to remain abreast of current developments so necessary to effectively supervise this essential service function.

Perhaps you may meet Mr. King during one of his visits to our interstate Valve and Tube Service Centres.

SILICON SEMICONDUCTORS

The design engineer is concerned with the construction of transistors only so far as it affects the performance that he hopes to achieve in a circuit. The advent of silicon transistors should be viewed solely with this in mind.

Germanium alloy techniques have become standard for all low-frequency applications, while germanium diffusion techniques allow a high frequency operating limit of tens of Mc/s. With this situation already established, silicon devices have to compete with germanium either in performance or in price; and it is, of course desirable for a new silicon device to have properties which are superior to those of germanium provided its introduction is an economic proposition. With the economics of the situation very much in mind, Mullard have always concentrated on the silicon techniques which could result in mass-production thus enabling realistic prices to be achieved. As the alloy technique was already well established in germanium, Mullard turned to its counterpart in silicon.

Silicon Alloy Devices—The silicon alloy technique has proved quite manageable, and a full range of devices is being developed. The first four—OC200, OC201, OC202, OC203—are already in production and many new silicon devices will follow in the very near future. We shall thus establish a range of devices comparable with their germanium alloy counterparts.

While high frequency performance is essential in many applications, this is not always so and there are, in fact, many design engineers who would prefer a device which meets audio requirements at the lowest possible price. The Mullard alloy range has been developed with this in mind.

Now that the development of the silicon alloy range has been achieved, and is going into production in hundreds of thousands, effort is being concentrated on diffusion techniques to provide higher frequency ratings and increased power. On the one hand, it is necessary to produce transistors capable of driving ferrite memory circuits at pulse repetition frequencies of 2.0 Mc/s and upwards; on the other hand, power transistors, silicon power rectifiers, and controlled rectifiers, are also needed. A complete range of possible silicon and germanium devices, consistent with mass production, high quality and competitive prices will ultimately become available to designers and circuit development engineers.

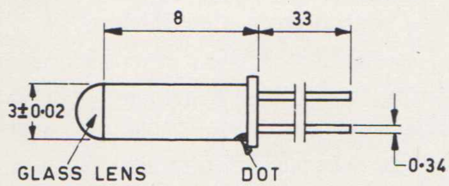
OAP12 GERMANIUM JUNCTION PHOTODIODE

The OAP12 is a germanium junction photodiode of the p-n alloy type. It is, in effect, a miniature photocell with a diameter of only 3mm and a length of 8mm. The photodiode may be biased to pass a saturation current virtually independent of the applied voltage. The application of luminous flux causes the saturation current to rise in proportion to the amount of illumination thus enabling the device to perform a control function.

Features of the OAP12 are sturdiness, long useful life, very small dimensions, high sensitivity, low noise level, high internal resistance, excellent response in the near infra-red region, and good electrical screening of the body of the cell.

By virtue of its high sensitivity, this new junction photodiode is suitable for a wide variety of applications without the need for amplification. The circuits associated with it can, therefore, be kept very simple.

The OAP12 will shortly be available in sample quantities.



DIMENSIONS IN MM.
OAP12

ABRIDGED ADVANCE DATA FOR OAP12

Characteristics

Peak spectral response		1.55	μ
Spectral response threshold		2.0	μ
Cell resistance		3.0	Ω
Sensitivity	>	5	μA/100 lux

Limiting Values

Max ambient temperature	45	°C
Max negative voltage	30	V
Max current	3.0	mA
Max dissipation	30	mW

Absolute Maximum Ratings

Inverse voltage	=	30	V
Inverse current	=	3	mA
Permissible junction dissipation	=	30	mW

Typical Characteristics

Sensitivity measured by means of a tungsten incandescent lamp (T_c = 2500 °K)	>	5 μA/100 lux
Sensitive surface (circular)	=	1 mm²
Dark current (at T_{amb} = 25 °C and at V = —10 V)	<	15 μA
Dark current noise (with a bandwidth of 1 c/s at a frequency of 1 kc/s and an inverse voltage of —10 V)	<	$3.10^{-12} A_{rms}$ per c/s
Internal impedance (from V = —0.5 V to —30 V)	>	3 MΩ
Maximum spectral response at	=	1.55 μ
Response threshold at	=	2 μ

The cut-off frequency (frequency above which the sensitivity is less than half the reference sensitivity) is 50 kc/s. The reference sensitivity is measured at 1 kc/s, V = —10 V and T_{amb} = 20 °C.

NEW TELEVISION TURRET TUNER NT3001

The Turret type multi-channel selector has proved superior in practice to other methods of channel selection in television receivers. Its main advantages are, briefly:—

(i) higher stability;
(ii) reduced oscillator radiation; and
(iii) more positive channel selection.

Individual sets of coils are used for each channel and may be adjusted, removed or replaced without affecting other channels.

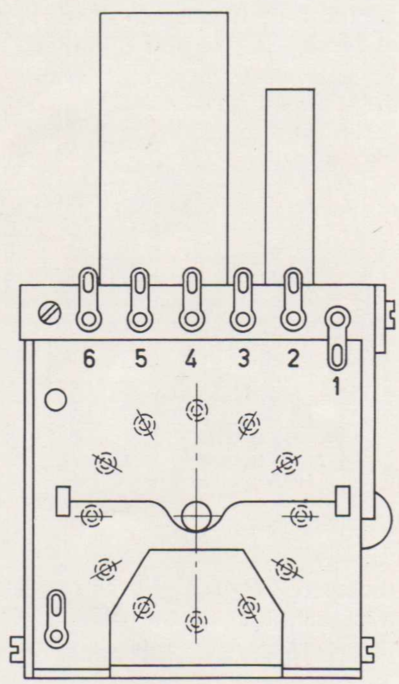
The Turret Tuner, type NT3001, has been designed around the new frame grid valve 6ES8/ECC189 and the 6BL8/ECF80. The new high-gain, Semi-Remote Cut-Off Double Triode 6ES8/ECC189 is used as a Cascode RF Amplifier, while the 6BL8/ECF80 functions as local oscillator and frequency converter. A circuit diagram of the Tuner is shown below.

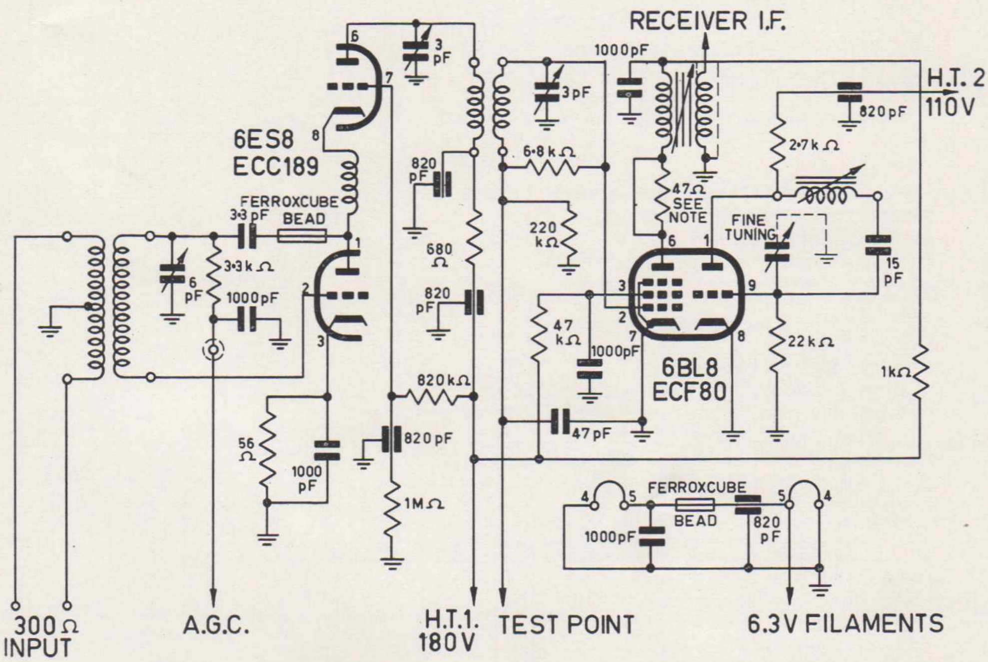
The input transformer is designed to terminate either a 300Ω balanced transmission line or a low impedance unbalanced line. In the latter case the unbalanced line should be connected between either end of the primary winding and the centre tap. The tuned secondary of this transformer is connected to the grid of the input triode of the cascode amplifier and also forms part of the neutralising network. The anode of the grounded grid stage is inductively coupled to the pentode section of the 6BL8/ECF80 frequency changer. The triode section of the 6BL8/ECF80 is used as an oscillator and negative temperature co-efficient ceramic capacitors are employed to reduce frequency drift during warm-up time. The Oscillator h.t. supply is derived from a separate external source in order that it may be independent of any variation in voltage with A.G.C. of the cascode stage.

The intermediate frequency output is transferred from the anode circuit of the frequency changer via a single tuned coupling transformer having a low output impedance. The tuned primary of this transformer forms the first section of a band pass filter, the second half of which is placed adjacent to the first I.F. valve. The low impedance characteristic of the connecting cable between tuner and I.F. strip allows the circuit designer a maximum of flexibility together with optimum performance. A 47Ω resistor in series with the primary of the I.F. transformer is normally bridged with a wire loop and the tuner may be operated with this resistor in or out of the circuit. Where primary damping is desired, the wire loop shorting the 47Ω resistor is cut and the ends of the wires separated. Ready access to the loop is obtained by removal of the plastic cap adjacent to the detent mechanism.

The gain of the NT3001 (almost twice that of the AT7580) together with its improved noise figure and A.G.C. characteristic provides superior performance and at the same time ensures freedom from patterning due to cross modulation. The fringe area performance eliminates the need for special receiver modification and contributes to the use of less elaborate aerial systems.

1 EARTH
2. I.F. OUTPUT
3 A G C
4. HEATER SUPPLY
5. H.T. SUPPLY No 2 110V
6. H.T. SUPPLY No. 1 180V





Note: Primary of the I.F. Transformer may be operated with a 47Ω series damping resistor by removing wire loop (see text).

FRAME GRIDS FOR TELEVISION

The new Mullard valve 6ES8/ ECC189 variable-mu frame grid Double Triode Cascode V.H.F. Amplifier, especially designed for use in television tuners, employs manufacturing techniques that have not previously been used in valves which are mass produced for entertainment purposes. *[See also Mullard "Outlook" Australian edition, Vol. 1 No. 6 November/December, 1958, page 58. Ed.]*

The frame grid is a rigid structure made to extremely accurate dimensions. The stiff frame allows the use of very fine grid wires which are wound in a fine mesh, located literally one hairbreadth from the cathode surfaces. Twenty of these grid wires twisted together are equal to the thickness of the average human hair.

The grid of a conventional receiving valve is essentially self-supporting, the rigidity being dependent on the stiffness of the wires used, whereas in the frame grid the individual turns of the winding are anchored into the side rods by a notching and clamping process. Electrically, the frame grid ensures well controlled characteristics, reduced risk of microphony, high slope, and a good ratio of slope to inter-electrode capacitance; this ratio may also be referred to as the "Figure of Merit." In the new 6ES8/ECC189,

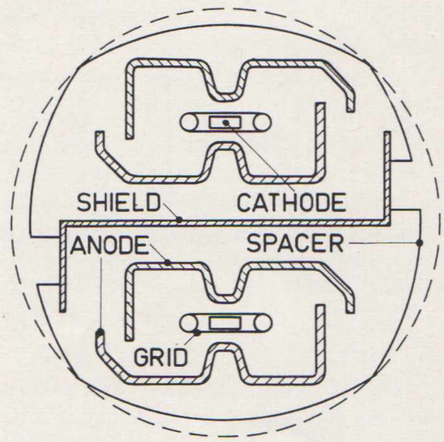


Fig. 1.

the space between grid and cathode is 57μ, half that of the 6CW7/ECC84.

The 6ES8/ECC189 anode is of an unusual shape, and results in several improvements over the conventional anode structure. Figure 1 shows this new anode and its location with respect to the cathode. It is formed of two sections, one of which is shown in Figure 2. The peculiar shape of the anode results in a reduction of anode to cathode capacitance variation *(when compared with a valve having a conventional anode)* with deviation

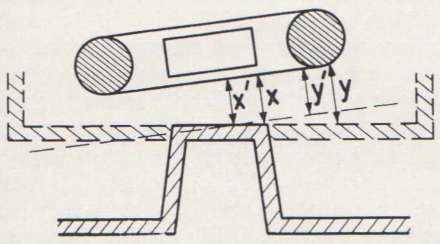


Fig. 2.

of the anode structure from its normal parallel position. From Figure 2 it may be seen that the maximum deviation of the actual anode (x'-x) is much smaller than the deviation (y'-y) occurring with a rectangular anode.

The movements between cathode and grid—sometimes the reason for microphony — are effectively damped with an additional mica spacer.

The introduction of frame grid valves for television is a significant and substantial advance, and the most recent step in the course of continuous development which has marked valve manufacture and receiver design from the very beginning.

Readers of "Outlook" might be interested to learn that the latest television tuner, manufactured by Standard Coil Products Co. Inc. of the U.S.A., is fitted with a Mullard Frame Grid Valve.

TECHNICAL DATA
6ES8/ECC189

SEMI-REMOTE CUT-OFF DOUBLE TRIODE CASCODE V.H.F. AMPLIFIER

HEATER CHARACTERISTICS

Heater Voltage, 6.3 volts   Heater Current, 0.365 amperes

DIRECT INTERELECTRODE CAPACITANCES

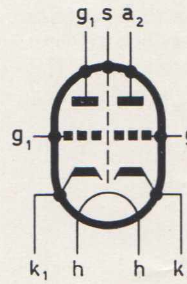
	Shielded	Unshielded
Grounded Cathode Section.		
Cag	1.9	1.9 pF
Cg (k + h + i.s.)	3.4	3.4 pF
Ca (k + h + i.s.)	2.4	1.7 pF
Cgh	max. 0.22	0.22 pF
Grounded Grid Section.		
Ca'g'	1.9	1.9 pF
Ca'k'	0.17	0.18 pF
Ck' (g' + h + i.s.)	6.3	6.3 pF
Ca' (g' + h + i.s.)	3.9	3.3 pF
Ck'h	3.0	3.0 pF
Grounded Cathode to Grounded Grid Section.		
Caa'	max. 0.015	0.045 pF
Cga'	max. 0.004	0.004 pF

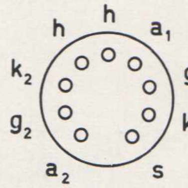
MAXIMUM RATINGS (Each Section):

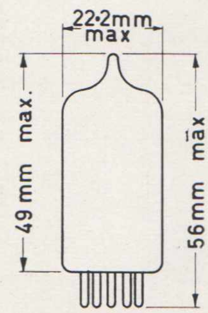
Anode voltage (without current)	550 V
Anode voltage	130 V
Anode dissipation	1.8 W
Cathode current	22 mA
Grid No. 1 voltage	—50 V
External Grid No. 1 resistance—	
Grounded cathode section	1.0 MΩ
Grounded grid section	0.5 MΩ
External resistance between cathode and heater	20,000 Ω
Voltage between cathode of grounded cathode section and heater	50 V
Voltage between cathode of grounded grid section and heater (Cathode positive)	150 V
(Maximum D.C. component, 130V.)	

TYPICAL CHARACTERISTICS (Each Section):

Anode voltage	90 V
Grid No. 1 voltage	—1.2 V
Anode current	15 mA
Amplification factor	34
Mutual conductance	12.5 mA/V
Grid No. 1 voltage for 0.01 of nominal mutual conductance	—9 V





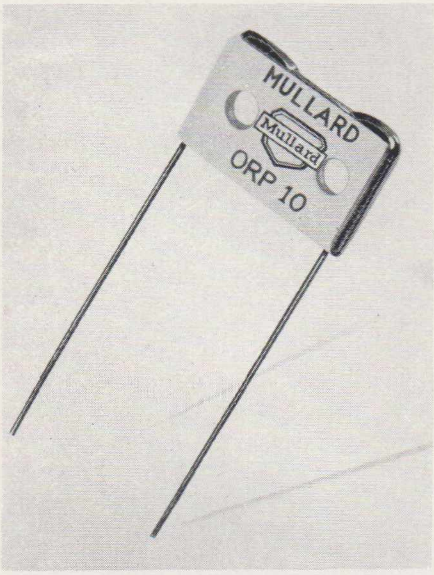


ULTRA-VIOLET TO INFRA-RED

A convenient starting-point for the consideration of photocells is the frequency spectrum — the familiar rainbow of colours and the 'invisible light' beyond its two ends.

Television bands are in the tens and hundreds of Mc/s region (wavelengths of tens of metres down to less than half a metre). Radar extends into thousands of Mc/s (centimetre wavelengths). Beyond this region are heat and infra-red, with wavelengths in millimetres and frequencies of millions of Mc/s. Next comes the very narrow band of visible light, with wavelengths of about 0.75 to 0.5 of a micron (a micron, represented by the overworked symbol μ, is 0.001 of a millimetre). The frequency is too astronomical to be worth quoting. Beyond the blue end of the light band are ultra-violet (0.3μ), X-rays, gamma rays, and cosmic rays. These wavelengths are so short that they are more conveniently measured in Angstrom units (A), that is 0.0001 of a micron.

The visible band, and its 'ultra' and 'infra' extensions, is shown in the table, with the shorter wavelengths at the bottom. The broadcast bands are off the top of the page, and X-rays, etc., are well below the bottom. The classes of cell in the right-hand column have their highest sensitivity in the wavebands which are indicated, with lower sensitivities in the neighbouring bands. The photoconductive cells (of which there are half a dozen kinds with different peaks) cover the near infra-red



ORP10 (Indium Antimonide)

region. The cadmium sulphide cell, and the caesium/oxidised silver cells, extend into the infra-red region.

For any particular application one chooses the kind of cell with the most suitable frequency range; and, where alternatives exist, a further choice is made in terms of the absolute sensitivity and the response time which are required. In the visible band, the caesium/antimony cell is most sensitive to daylight, and the caesium/oxidised silver cell to artificial light (filament lamps). The human eye has a peak sensitivity midway between these two, and a response which, of course, just covers the visible band.

The frequency response of any cell can be deliberately restricted by means of tinted filters, which will shield the cell from all frequencies outside a narrow band. If operation far into the ultra-violet region is required, the glass bulb of the cell will act as an unwanted filter, and a quartz window may be used as in some photo-multipliers.

In some applications it is undesirable to have any visible light. Filters are then placed in front of the light source so that only infra-red ('black light') remains.

BAND	WAVELENGTH		PHOTOCELLS
	μ	Å	
Far infra-red	100 to 10	1,000,000 to 100,000	
Near infra-red	10 to 0·75	100,000 to 75000	Photoconductive; Phototransistor
Red Orange Yellow	0·75 to 0·65 0·65 to 0·59 0·59 to 0·53	7500 to 6500 6500 to 5900 5900 to 5300	Caesium/ oxidised silver; Cadmium sulphide
Green Blue Violet	0·53 to 0·49 0·49 to 0·42 0·42 to 0·4	5300 to 4900 4900 to 4200 4200 to 4000	Caesium/ antimony
Ultra-violet	0·4 to 0·18	4000 to 1800	Caesium/antimony

1·0mm = 1000μ = 10,000,000Å

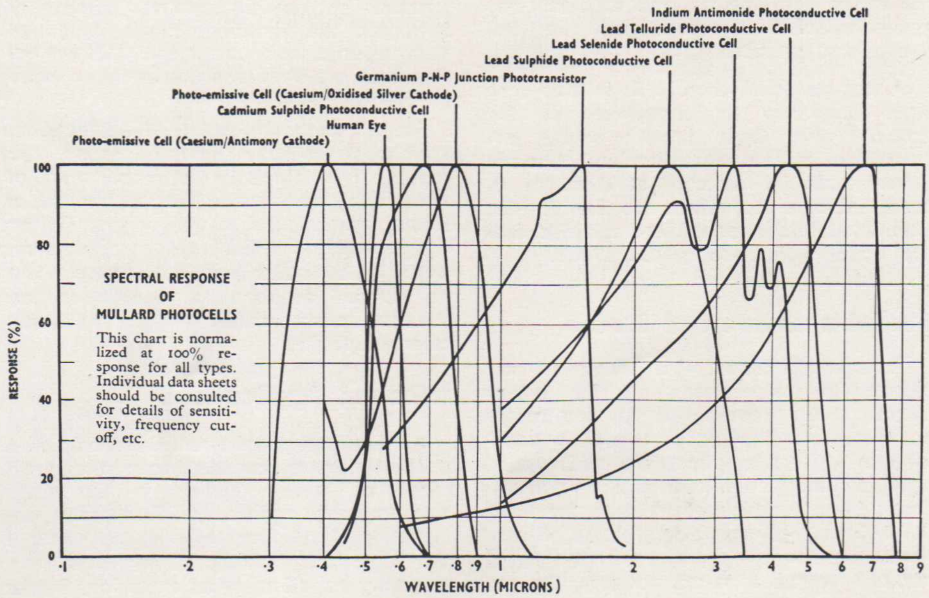
Types of Cell

There are three main groups of photocells, each of which operates on a different principle:— photovoltaic, photoemissive, and photoconductive. The photoconductive cells can be considered to include phototransistors and photodiodes.

Photoemissive Cells

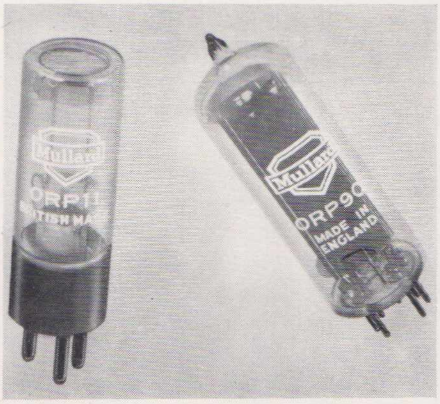
A photoemissive cell consists of a rod (the anode) and a half-cylinder of metal (the cathode). The cathode surface may be caesium/antimony (blue-sensitive) or caesium/oxidised silver (red-sensitive). A suitable voltage is applied across the cell. When light falls on the cathode, electrons are emitted and a current is developed in the anode circuit in proportion to the applied lighting intensity. The bulb containing the electrodes may be evacuated or gasfilled, according to whether one requires a stable and linear response, or maximum sensitivity for use where incremental light change is a factor.

Photomultipliers are elaborate emissive cells in which light produces electrons in one stage, and these electrons then produce a greater number of electrons from the anode by secondary emission. With a chain of, say, ten secondary emission stages, a large output current is obtainable from quite a small light input. Each stage in the tube is held at a higher voltage than the preceding stage. When these tubes are



used for detecting and measuring gamma radiation and the like (which a photocathode cannot see) a special input arrangement is incorporated in the tube. The radiation falls on a fluorescent screen, which then produces the required light.

The most elaborate photomultipliers have special focusing and accelerating arrangements which ensure not only high gain but also a very fast response which enables the tube to deal with a rapid succession of input signals without confusing them.



ORP11 and ORP90 (Cadmium Sulphide)

Photoconductive Cells

Recent years have seen great developments in photoconductive cells. The principle is that when light (or infra-red) falls on some particular chemical compounds, the resistance of the compound changes. Thus, if a voltage is applied, the current varies with the light. The compounds include cadmium sulphide, lead sulphide, lead selenide, lead telluride, and indium antimonide, which have peaks, in that order, extending from red almost to the far end of the near infra-red. Other types are under development, and no doubt the photoconductive coverage will be improved and extended.

A feature of all these cells is their very great sensitivity in comparison to the emissive cells. Their output is several mA instead of a few µA, therefore infra-red sources can be detected at distances of many miles; a fact which accounts for the original development of lead sulphide cells for aircraft detection in the 1940's.

Phototransistors and Diodes

It is well known that transistors are affected by temperature. Light has similar effects, if the transistor is not constructed in a can or otherwise protected. A transistor in which these effects are made use of will, in a very simple circuit, give a collector current which varies with the light. It will also provide amplification. Phototransistors have a peak sensitivity placed usefully in the infra-red between the red sensitive emissive cell and the lead sulphide type.

Among current developments is a highly sensitive germanium photodiode which may be used in an extremely simple circuit without amplification.

63TV (Lead Telluride)

Applications

Emissive cells are much used for counting objects on moving belts. When a certain number of objects have successively interrupted the beam, it is easy to arrange for them to be diverted into a separate package and for counting to start again. Equal batches are thus obtained at high speed. With suitable cells and filters, sorting by colour is possible.

Interruption of a beam (perhaps of 'black light') can be used to detect objects which are in the wrong place: either a safe-breaker in a bank vault, or an operator's hand which is dangerously close to the moving parts of a press. (The circuit for this would have to be designed to 'fail safe,' so that a circuit failure would stop the press as certainly as an intruding hand.) Intruder systems can be made to cover a considerable area if two or three mirrors are used.

Positions of workpieces (such as the paper in a printing machine) can be checked and corrected by a photocell device. The dimensions of, say, a steel rod emerging from a mill can be continuously checked by suitably arranged beams of light, and the variations can be automatically recorded and corrected. 'Callipers' of this kind are very convenient in awkward or hot situations.

Simple measurement of daylight can be used to switch street lights off or on. The varying light through the sound track of films is, of course, the normal method of sound reproduction in the cinema. Colour detection has special uses in chemistry, where a particular part of a process can be stopped as soon as a solution has changed colour or has become sufficiently clear or cloudy.

Infra-red Applications

Applications of infra-red photoconductive cells are very varied, hence the great range of types. 'Seeing in the dark' was an early application. Continuous observation of oil furnaces is widely used; if the flame goes out, the oil supply is automatically cut off to avoid explosion. Smoke detection—to comply with legal requirements, to detect fires, or to ensure good combustion — is growing in importance. Intruder alarms and aircraft detection have already been mentioned. Overheating of bearings can be readily detected. There are many purely scientific uses in astronomy, chemical analysis and measurement, and so on. An interesting wartime development of infra-red was its use for telephony. A modulated beam of infra-red can be very accurately beamed, and it gives nothing away.

Photocell methods have advantages in all sorts of applications, and their use will no doubt grow. Light is fast and flexible, it has 'no moving parts', it weighs nothing. It can work miles away, and it can get into the most inconvenient corners. It can even be invisible.

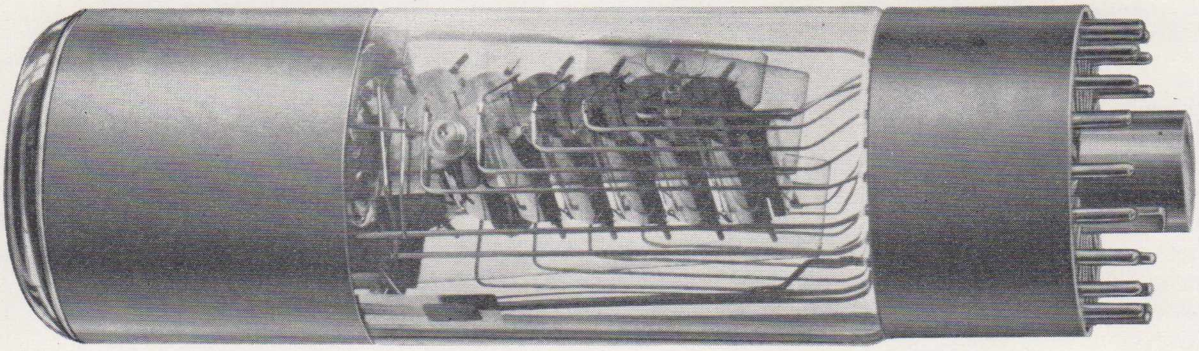
Circuits

Photocell circuits are usually quite simple. Many types of cell can operate a relay directly. With others, a simple amplifier is used, and a common practice is to chop the incoming light with a revolving shutter. This gives a convenient a.c. output from the cell, and the whole set-up responds only to the signal and not to the background lighting.

As with any other electronic device, the circuit must be designed in accordance with the published limiting values for the particular cell. The maximum voltage and current limits are important; and, especially with the conductive types, the proper temperature conditions must be provided.

61SV (Lead Sulphide)

A NEW HIGH DEFINITION PHOTOMULTIPLIER TUBE



A recent addition to the existing range of Mullard Photomultiplier Tubes, the 56AVP has an exceptionally high definition which is specifically required in scintillation counting and nuclear radiation spectrography.

One of the most important requirements of a Photomultiplier intended for very high definition work is that differences in the transit times of the electrons through the tube must be negligible; otherwise the tube will not accurately resolve extremely short signals received in quick succession.

In the 56AVP, transit time differences under typical operating conditions may be kept down to 0.3 millimicroseconds — an improvement of about 100 times over conventional tubes. As a result, the width of the output pulse delivered by the 56AVP can be as little as 2 millimicroseconds at half height, and the rise time of the same duration.

Advanced Electron-Optical System

A specially designed Electron-Optical System, consisting of the Photocathode, a Focussing Electrode, an Accelerator and a Deflector Plate reduces the transit time to 0.3 millimicroseconds. The Photocathode is curved so that the path lengths to the first multiplier stage are approximately equal for electrons leaving any part of its useful area. The Focussing Electrode and the Accelerator act to concentrate the electrons into a single, narrow path, and to compensate for inequalities in their initial velocities. The Deflector Plate directs the electrons on to the first of the secondary cathodes.

The uniformity of transit times to the first multiplier stage is maintained throughout the tube by careful shaping of the secondary cathodes, and by additional focussing electrodes, situated between each multiplier stage, which progressively narrow the electron beam from stage-to-stage despite the rapid growth in the number of electrons.

High Gain, High Peak Currents

In the interests of economy and practicability it is desirable to dispense with an external amplifier. The 56AVP has therefore been designed to provide a peak anode current of 1A—sufficient for direct use. At values up to 300mA the anode current has a linear relationship with the incident light flux so that the tube can be used for measuring the energies of incident radiation. For some purposes both the initial focussing electrode and the deflector plate may be used to control the output current produced by a particular input level.

The high anode peak currents delivered by the tube are made possible by a 14 stage multiplier incorporating opaque silver magnesium secondary cathodes, and giving, under typical operating conditions, a gain of 10^8 or more, corresponding to an average cathode sensitivity of 50 microamps per lumen and an average sensitivity of 5,000A per lumen.

Brief data for the tube may be found below:—

Photocathode (end-viewing)

Minimum useful diameter	42mm
Peak spectral response	4,200Å (±300Å)
Average sensitivity	50 microamps/lumen

Multiplier

Minimum gain (at total voltage of 2kV)	10^8
Maximum peak anode current	1A
Average anode sensitivity (at 2kV)	5,000A/lumen
Dark current (at gain of 10^8)	less than 5 microamps
Output pulse (at 2kV)	
rise time	2 millimicroseconds
width at half height	2 millimicroseconds

Mechanical

Maximum overall height	190mm
Maximum seated height	175mm
Maximum diameter	55mm
Base	20-pin (bidecal)

SILICON POWER RECTIFIERS

For application in television receivers the Mullard-preferred silicon junction diode is the OA210.

With an inverse voltage rating of 400V maximum, an average forward current of 0.5A, and a peak forward current of 5A at a mounting base temperature of 125°C, this hermetically sealed rectifier offers increased efficiency in the power supply section of television receivers. Operation at ambient temperatures up to 70°C with a capacitive input filter of not greater than 200μF is permitted provided the effective input resistance Rt* is not less than 4Ω. The attached curves depict average forward and reverse characteristics; operating conditions are shown for the OA210 as a half wave rectifier and for a pair as full wave voltage doubler for the two possible modes of connection. As one of these necessitates an insulated A.C. electrolytic capacitor the alternative connection is usually more attractive from the economic point of view.

It should be noted that a series input resistance of only 4Ω is the minimum necessary with voltage doubling circuits as each diode is conducting for not more than half the cycle alternatively because of the bi-phase connection. If it is desired to use a negative temperature co-efficient resistor in addition to, or instead of the normal series input resistor to ease the peak voltage ratings necessary for the filter capacitor, it is essential to observe that the total effective input resistance in circuit when the supply is operating at maximum output current is still not less than the specified value of 4Ω. Practical experience to date indicates that in television receiver power supplies up to 400mA of high tension current can be supplied by the normal voltage doubling circuit without the need for heat sinks.

Appendix: Series connection of silicon diodes such as the OA210 is permitted provided means are adopted to take care of possible production spreads in reverse resistance. Indeed, this problem is not unlike the series connection of electrolytic capacitors where inequalities in leakage voltage/current characteristics result in unequal voltage sharing. With silicon rectifiers the situation is analogous in that the diode with the highest reverse resistance (lower leakage current) will assume a greater than its normal share of reverse voltage—the ratings can be exceeded and the diode breaks down. For these reasons it is recommended that where two OA210's are series connected, each unit be shunted with a resistor of not greater than 3.9 MΩ.

When a transformer is present between the mains and the diode the additional resistance R1 is calculated as follows:—

$$*R_t = R_s + N^2 R_p + R_1$$

Where Rt = minimum required circuit resistance.

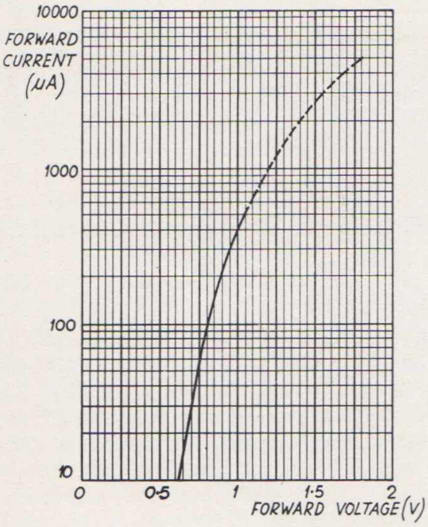
Rs = DC resistance of secondary. (For full wave circuits Rs = DC resistance of half secondary.)

Rp = DC resistance of primary.

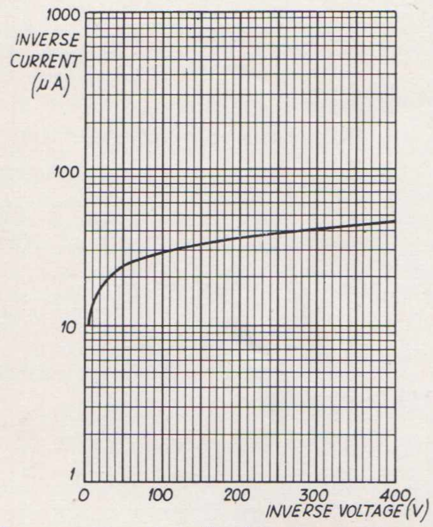
N = Turns Ratio $\frac{N_s}{N_p}$

R1 = Additional resistance if necessary.

Characteristics

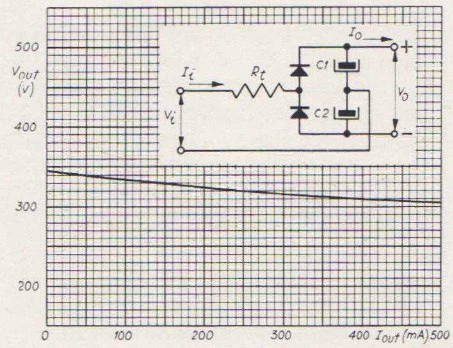


Forward—at a mounting base temperature of 125° C.

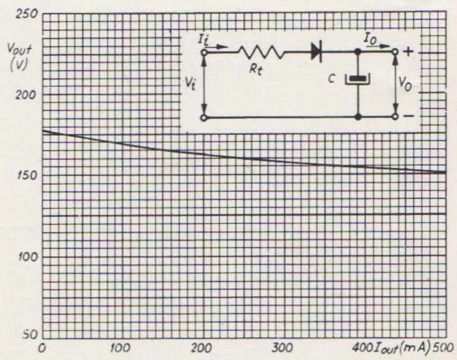


Inverse—at a mounting base temperature of 125° C.

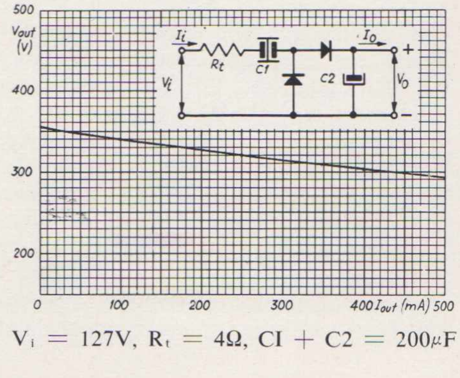
Regulation Curves



$V_i = 127V$, $R_t = 4\Omega$, $CI = C2 = 200\mu F$



$V_i = 127V$, $R_t = 4\Omega$, $C = 200\mu F$



$V_i = 127V$, $R_t = 4\Omega$, $CI + C2 = 200\mu F$

SIMPLE VALVE MEASUREMENTS

This article is the first of a series to be published in the "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.

Assuming that the reader already has a working knowledge of the principles of the thermionic valve no exposition of the basic theory has been included, but in this first article certain explanations are given.

In view of the limitations of these methods of measurement, coupled with the spread of characteristic curves between individual valves, close agreement between calculated and measured valves cannot be expected, and errors of up to 15% or even more, should be accepted.

1 DIODE

If a source of direct voltage is connected between the anode and cathode of a diode, the anode being positive, electrons emitted from the cathode are attracted to the anode. This flow of electrons is termed the **anode current.**

If the cathode temperature is maintained constant, the value of the anode current (I_a) is governed by the anode voltage (V_a). (See Fig. 1.) Increase of anode voltage results in an increase of anode current.

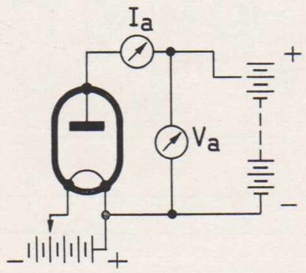


FIG. 1.
BASIC CONNECTIONS OF A DIODE.

1.1 I_a/V_a Characteristic

If the anode current is plotted against the anode voltage for a constant cathode temperature, a curve of the form shown in Fig. 2 is obtained. The fact that the graph is not a straight line indicates that a diode does not obey Ohm's Law.

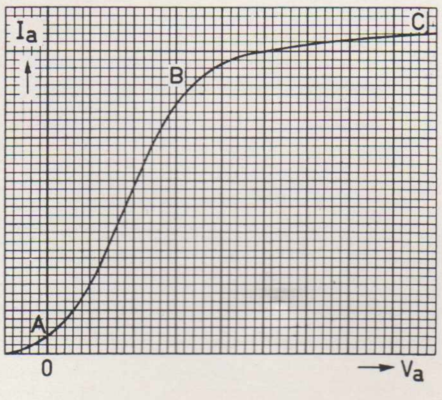


Fig. 2.—I_a/V_a Characteristic of a diode. The part B-C shows the saturation effect.

The curve can be considered as consisting of two parts; (1) the part A-B where an increase in anode voltage results in a substantial increase in anode current, and (2) the part B-C where a further increase in anode voltage produces practically no increase in anode current.

It will be seen from this curve that at $V_a = 0$, and even when V_a has a small negative value, some anode current flows. The explanation is that the electrons leave the heated cathode with some initial velocity. If, then, the anode is connected directly to the cathode so that it is at cathode potential ($V_a = 0$), or even if the anode is given a small negative potential, a few electrons will reach the anode.

1.2 The Child-Langmuir Three-halves-Power Law

Over the range A-B the anode current for a diode having a wire filament along the axis of a cylindrical anode is given by the Child-Langmuir three-halves-power formula.

$$I_a\,(\text{mA}) = 14{\cdot}65 \times \frac{l}{R} \times 10^{-3} \times V_a^{3/2}$$

where l = length of anode
R = internal radius of anode.

1.3 Richardson's Law

The flattening of the curve in the region B-C is due to the fact that the anode is collecting practically all the electrons which the cathode is able to emit at its prevailing temperature. The valve is then said to be **saturated.**

At a higher cathode temperature (higher filament current) saturation occurs later, as indicated by the family of curves shown in Fig. 3.

The saturation current (total emission) of a diode is given by Richardson's Law:

$$\text{Total emission (mA)} = aAT^2\epsilon^{-11600\,\phi/T}$$

where a is the effective emitting area of the cathode
T is the absolute temperature of the cathode
and A and ϕ are thermionic emission constants determined by the chemical nature of the cathode

For the GRD7 diode recommended for these experiments, Richardson's Law can be simplified to:

$$\text{Total emission current (mA)} = 3411T^2\epsilon^{-52500/T}$$

1.4 Internal Resistance of a Diode

The departure from Ohm's Law in the behaviour of a diode indicates that the internal resistance of the valve is not constant, but varies with the anode voltage. Since, from Ohm's Law, $R = \frac{E}{I}$ the internal resistance (r_a) of a diode at any point on its I_a/V_a curve is:

$$r_a = \frac{\text{small change in anode voltage}}{\text{resulting change in anode current}} = \frac{\Delta V_a}{\Delta I_a}$$

(To be continued)

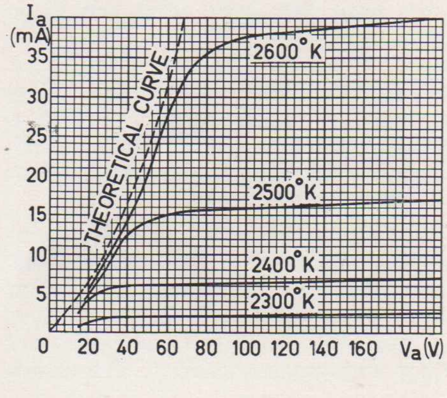


Fig. 3.—I_a/V_a Characteristic of a diode at various cathode temperatures.

FIRST INDUSTRIAL MASER IN OPERATION

A Maser (M.A.S.E.R.—microwave amplification by stimulated electromagnetic radiation) amplifier, thought to be the first working assembly to be built in the United Kingdom by an industrial laboratory, came into operation recently at Mullard Research Laboratories, Salfords, Surrey.

Construction of the Maser and investigation of its properties and performance has been carried out in the Laboratories' Solid State Physics Division where considerable work on semiconductor effects at low temperatures is being done by a group of scientists led by Dr. J. C. Walling.

Maser amplifiers are a recent scientific development which make use of the natural oscillations of the paramagnetic ions in certain crystalline substances—ruby for example. One of their chief uses lies in their ability to give useful amplification of very weak radio signals without producing unwanted signals which would otherwise swamp them.

One application of the device, which has already proved successful, is in radio astronomy for the amplification of very small signals from distant radio stars.

The Mullard Maser, which was constructed in co-operation with the Royal Radar Establishment, Malvern, operates at a wavelength of 10 cm in the 'S' band and at a temperature of 1.7°K (approximately -271 degrees centigrade). Investigations to attain higher frequencies and operating temperatures are being actively pursued at Salfords and Dr. K. Hoselitz, head of the Solid State Physics Division, Mullard Limited, indicates that there is a possibility of Master amplifiers operating at higher frequencies at room temperatures in the future.

TRANSISTOR CURRENT GAIN

When designing amplifier circuits using general purpose transistors it may appear that the selection of a transistor having a high α will naturally result in the achievement of high stage gain. This is not necessarily so as a compromise must be reached between gain and stability. With transistor types having a lower order of current gain excellent circuit stability may be ensured simply and economically whereas with higher α transistors an appreciable proportion of the maximum theoretical gain must be sacrificed in the interest of stability and the base divider current drain tends to become comparable with the transistor collector current.

Additionally there is a variation of gain with life and from the basic relationship: —

α′ (common emitter current gain) = α (common base current gain)/(1-α) it may be readily observed that a greater variation in α′ for a given variation in α is to be expected as α tends towards unity.

Designers may now decide for themselves whether they will engineer for high gain, with the need for greater d.c. stabilisation, and larger changes of gain with life; or lower gain per stage with greater stability. The choice is fundamental and a compromise inevitable.

The availability of the OC75 ensures that this choice is available to the designer at the three useful gain levels provided by the OC70, OC71 and OC75. Where the drive power is limited and amplifier gain with the OC71 is marginal, the OC75 will provide higher power gain.

Abridged Advance Data for OC75 Small Signal Characteristics at $T_{junction} = 25°C$

α′ at low frequencies			
	min	60	
	average	90	
	max	130	
fα′		8	kc/s
fα′ at $V_c = -6V$,	$I_c = 1mA$	900	kc/s

Limiting Values (absolute ratings)

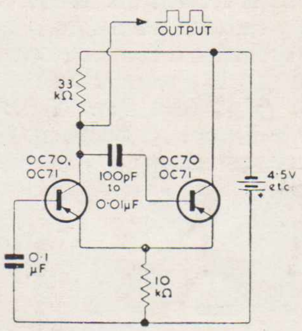
Collector voltage (grounded base or grounded emitter)		
$V_{c(pk)}$ max	–30	V
$V_{c(av)}$ max*	–20	V
V_c max (d.c.)	–20	V
Collector current		
$i_{c(pk)}$ max	50	mA
I_c max*	10	mA
Emitter current		
$i_{e(pk)}$ max	55	mA
I_e max*	12	mA

*averaged over any 20ms

AMATEUR EXPERIMENTERS COLUMN

MULTIVIBRATOR

One possible use is as a 'noise source' for finding a faulty stage when servicing radio receivers. The coupling capacitor may be made variable or switched according to individual choice. The values shown on the circuit will give frequencies of approx. 7kc/s and 100c/s respectively.



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