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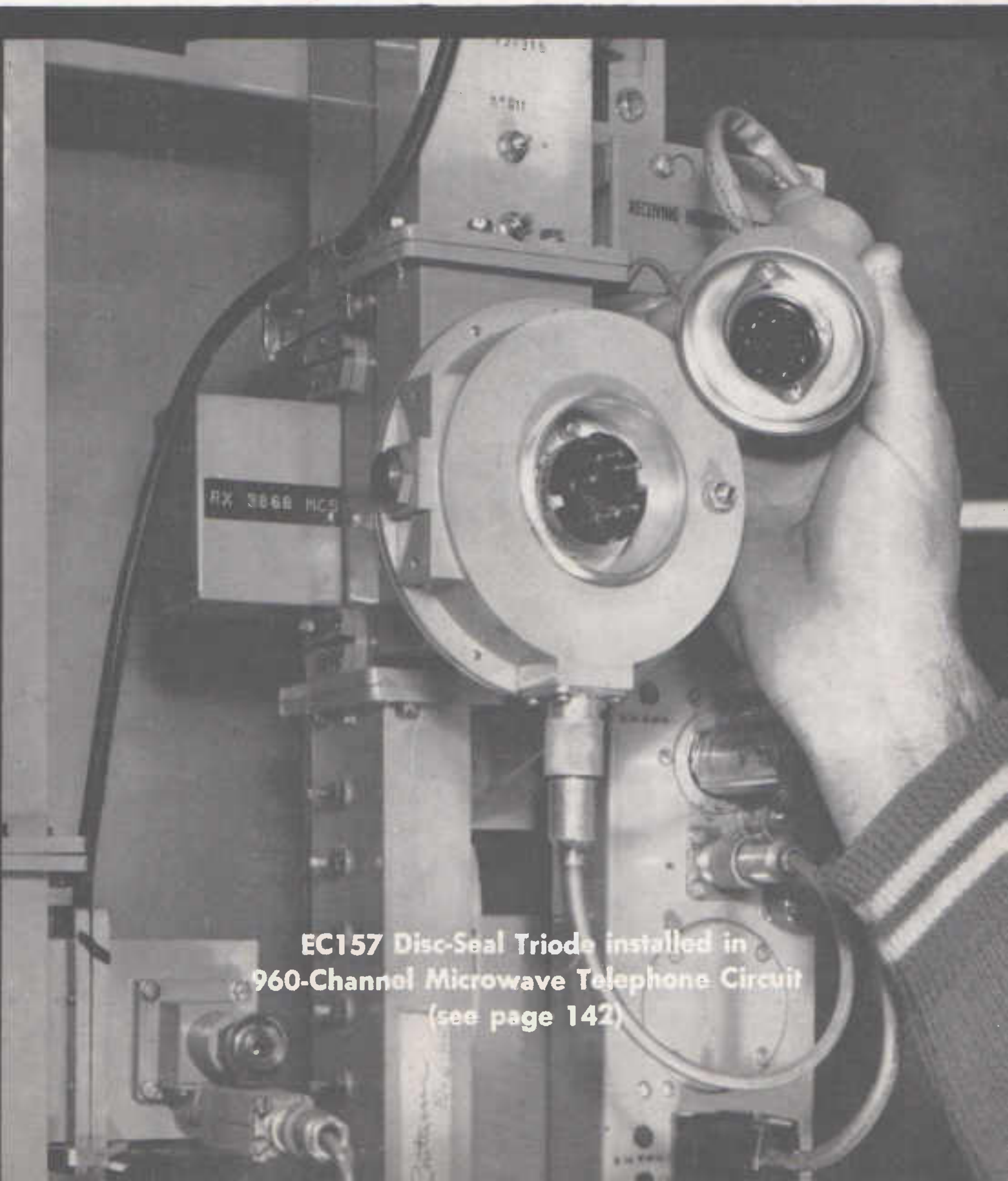

EC157 Disc-Seal Triode installed in 960-Channel Microwave Telephone Circuit (see page 142)

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Design of Circuits Using Cadmium Sulphide Photoconductive Cells

A graphical approach, analogous to that employed with vacuum tubes, is applied to the design of circuits using cadmium sulphide photoconductive cells. This method enables optimum cell response to be obtained while ensuring that the maximum ratings of the cell are not exceeded—a result which may not be achieved if cut-and-try design procedures are adopted.

Cadmium sulphide (CdS) photoconductive cells have a light-sensitive element of cadmium sulphide (a semiconductor) across which the terminals are connected. In practice, they may be regarded as resistors in which the value of resistance decreases with increasing illumination. The external voltage applied to the terminals may therefore be AC, or DC of either polarity.

The spectral response of cadmium sulphide extends over most of the visible spectrum with a broad peak in the red to near infra-red region. Thus tungsten filament incandescent lamps are most suitable as sources of illumination. The exact spectral distribution of the radiation from such a lamp is expressed by its *colour temperature* which is approximately 2700°K. In the sensitivity curves shown in Fig. 1, an incandescent lamp was used in determining the characteristics. Thus these curves may be used directly, provided that the cell is illuminated by a similar light source. With other light sources, it is usually sufficient to determine the sensitivity of the source/cell arrangement experimentally.

The rise and decay times of CdS cells are too long for them to be used with modulated light for sound reproduction, but they may generally be used with fluctuating light levels in control circuitry. Since the rise and decay times are shorter at high illumination levels, the highest possible illumination level should be used if rapid response is required in on/off switching circuits.

TABLE 1
Philips CdS Photoconductive Cells

Type	Sensitive Area (sq. inches)	Sensitive Direction	Basing
B8 731 03	0.09* approx.	End-on	Wire leads
B8 731 04	0.09* approx.	Side	Wire leads
ORP11	0.194*	End-on	3-pin
ORP30	0.70	End-on	Octal
ORP50	0.078	End-on and side	Wire leads
ORP60	0.000388	End-on	Wire leads
ORP61	0.000388	Side	Wire leads
ORP63	0.023	Side	Wire leads
ORP90	0.28	Side	7-pin Miniature

* Total area to be illuminated including metallic strips

The sensitivity of cadmium sulphide decreases with increase in ambient temperature, but this effect is generally small enough to be neglected, particularly at higher levels of illumination.

Advantages of CdS Cells

There are several groups of light sensitive devices available in the Philips range. Each group is to be preferred for some particular applications, but a detailed analysis is outside the scope of this article. Cadmium sulphide photoconductive cells are very versatile devices, so that for general use *it is always advisable to consider the possibility of using them, except where there is a requirement such as high repetition rate of operation or ultra-violet sensitivity.*

Briefly, the main advantages of cadmium sulphide cells are:

1. High lumen sensitivity.
2. No following amplification needed in many cases.
3. Low cost.
4. Simple circuitry (as low impedance sources they can often drive a relay directly).
5. Simple power supply requirements.
6. Small sizes available.

Philips CdS Cells

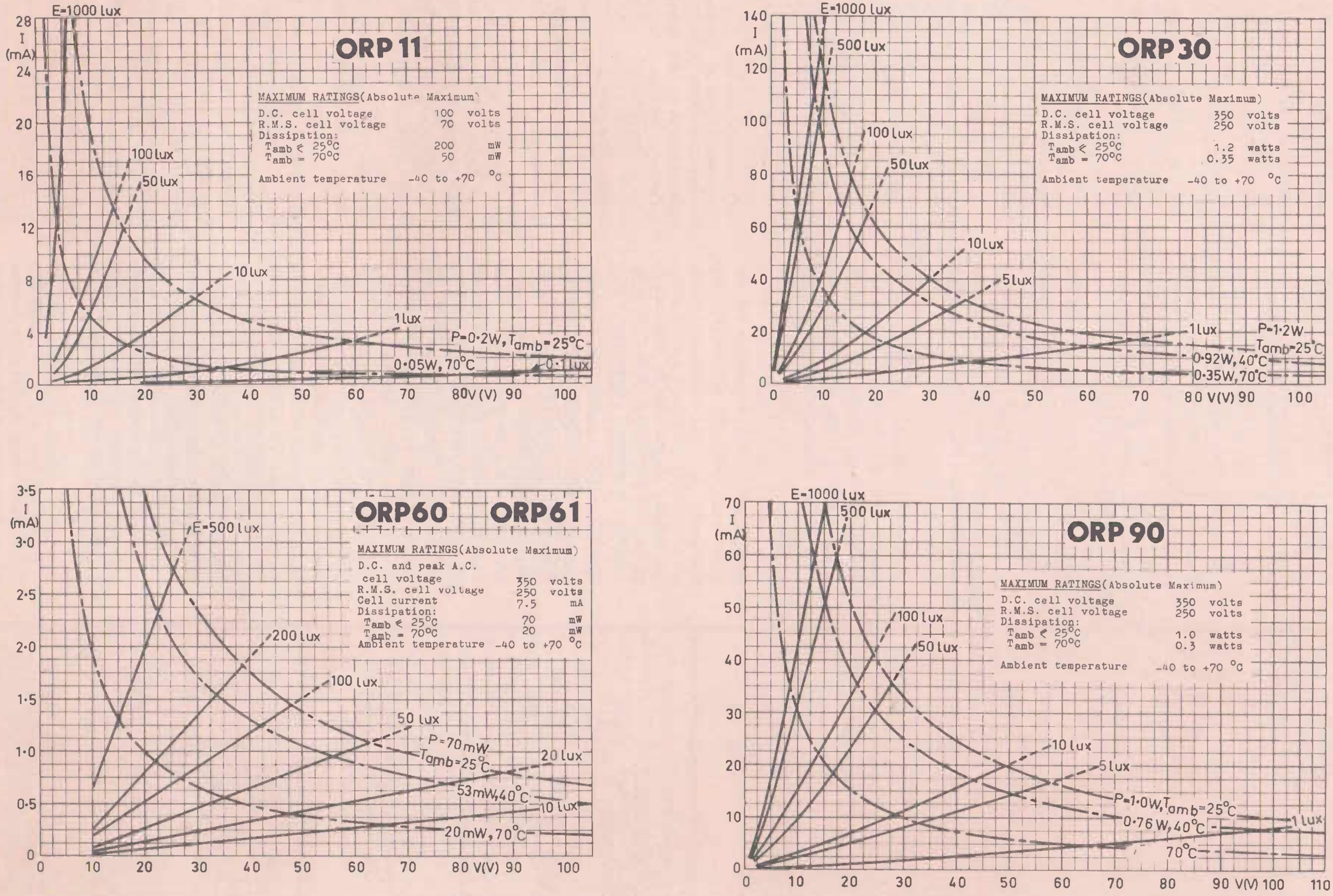
Some details of the currently available range of Philips CdS cells are given in Table 1. Further information on the characteristics and dimensions of four of these types appears in Figs. 1 and 2 respectively.

Choice of Cell

The choice of a particular type of CdS cell depends on the factors of available space and required sensitivity. The ORP30 should be selected when maximum sensitivity is necessary and space is not a consideration. Types ORP60 and ORP61 should be used when the smallest size is essential and a

Fig. 1. Sensitivity Characteristics of four types of CdS Photoconductive Cells.

Colour temperature of light source 2700°K.



N.B. 1 lux = 1 lumen/sq. metre; 1 foot-candle = 1 lumen/sq. foot = 10.764 lux.

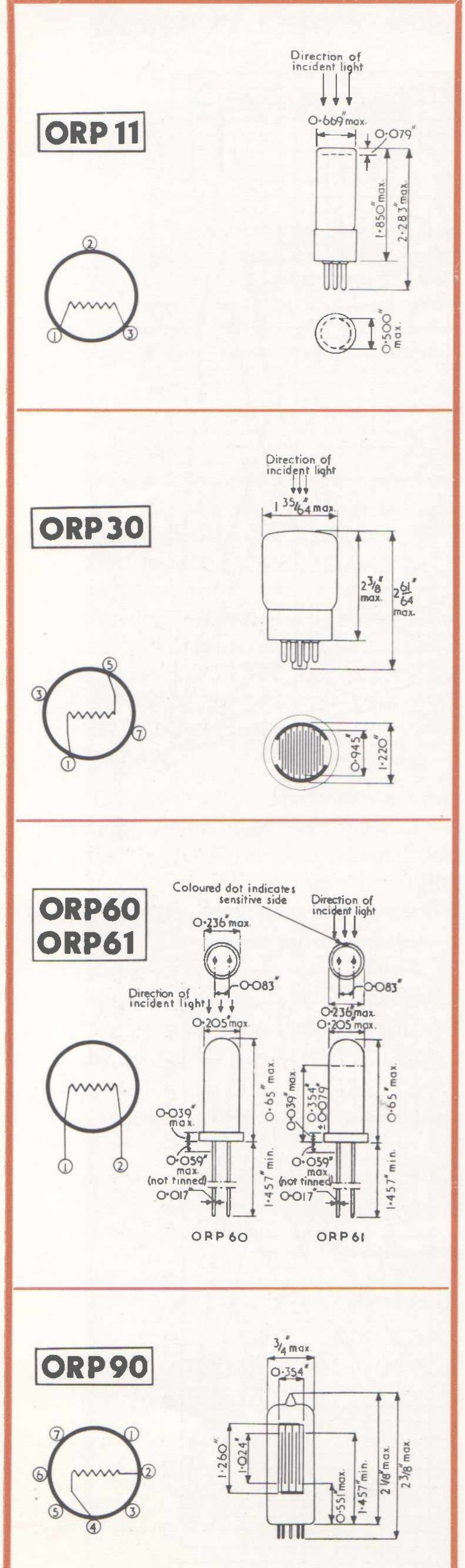


Fig. 2. Dimensional drawings and basing connections of four types of CdS photoconductive cells.

lower sensitivity can be tolerated. The other types represent compromises between these requirements.

Choice of Operating Conditions

Operation of a photoconductive cell within the permissible ratings is assured if the operating conditions are determined by plotting load lines on its characteristic curves—a method used in the design of valve circuits.

Of primary importance in the design is the maximum permissible power dissipation of the cell, which must not be exceeded in any circumstance. This limit decreases with increase of ambient temperature.

Other limitations, which must be taken into account are the maximum variation likely to occur in supply voltage, the differences between the characteristics of individual cells, and the tolerance on the resistance of the load. In a relay circuit, the resistance of the relay coil normally constitutes the load.

Sensitivity characteristic curves are shown in Fig. 1 for the CdS cells ORP11, ORP30, ORP60/61 and ORP90. The family of curves through the origin (solid lines) shows cell current (I) as a function of applied voltage (V), with illumination (E) as parameter. The curves resemble those of a triode vacuum tube, with the control grid voltage as parameter. As these curves apply to average illumination of the cell, a design objective should be to illuminate evenly the whole active area of the cell. The dashed lines indicate the permissible dissipation at several ambient temperatures, 70°C being the maximum permissible temperature.

Steps in Design Procedure

1. Determine the maximum ambient temperature at which the cell will be used. This confines the operation of the cell to the area below the appropriate maximum dissipation curve, represented by the dashed line AB in Fig. 3.
2. Select a suitable load resistance and supply voltage. For high incremental sensitivity, that is, a large current change for a given change in illumination, the resistance of the load should be less than that of the cell, as the latter is then the major factor in determining the current. This requirement calls for the steepest possible load line which does not intersect the maximum dissipation curve. For maximum absolute sensitivity, that is, maximum current for a given illumination, the load line should approach the dissipation limit as closely as possible.

   In the following discussion it will be assumed that both the foregoing requirements are to be met, in which case the load line will be tangential to the dissipation curve at the maximum anticipated illumination. This is illustrated in Fig. 3 where OX represents the current voltage characteristic of the cell at the maximum anticipated illumination, and the slope of line CD represents the minimum permissible load resistance for these conditions. OD represents the corresponding maximum supply voltage. This is a limiting case and for some specific applications it may be preferable to choose a load line of different slope which should, however, lie wholly within the area below the curve AB.
3. Consider the tolerances on the supply voltage and the resistance of the load. Referring to Fig. 3, OJ represents the lower limit of the supply voltage, and the slope of the line JK represents the maximum value of the load resistance. Operation of the cell will now always be confined to the area CDJK. The distance between lines CD and JK gives the possible variation in current at a given illumination. EF is the nominal load line.

Circuits for Continuous Indication or Control

In this class of circuit, the output is a meter indication or a control voltage proportional to the cell current, which is in turn proportional to the illumination of the cell.

Normally, an instrument using a circuit such as this will be calibrated against a reference standard at several points in its working range, and the calibration repeated if the photoconductive cell is replaced by another. Suitable operating conditions for the cell can be determined by applying the design considerations mentioned so far.

On-Off Switching Circuits

In this application, the photoconductive cell is normally illuminated by a control light source, the interruption of which causes a relay to be released. A typical example is

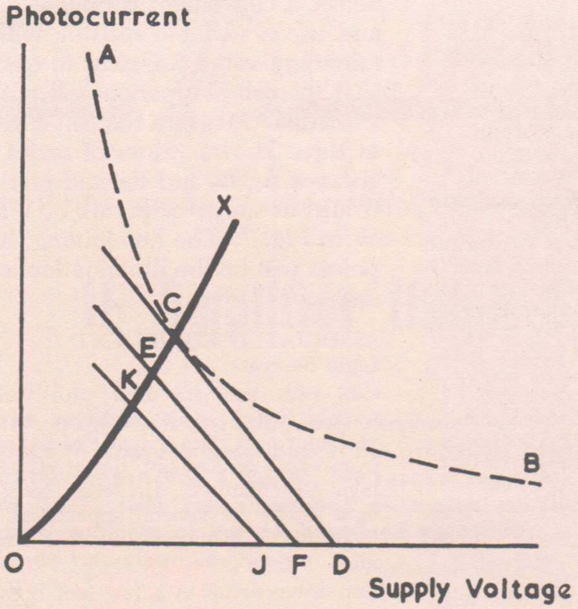


Fig. 3. Simplified photoconductive cell characteristic illustrating choice of load line for continuous control. AB = a dissipation limit. OX = an illumination level. EF, CD, KJ = nominal, min. and max. load lines.

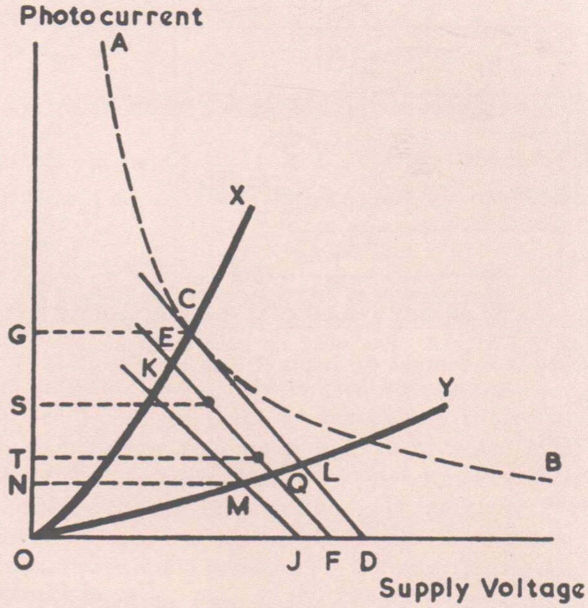


Fig. 4. Simplified photoconductive cell characteristic illustrating choice of load line for on/off switching. AB = a dissipation limit. OX = an illumination level. EF, CD, KJ = nominal, min. and max. load lines. OY = lower illumination level. OG, ON = upper and lower current limits. OS, OT = typical relay operate and release currents.

the photo-electric control of elevator doors. All the previous design considerations apply in this case, together with additional limitations on the current. These are a minimum current (light source interrupted) below which the relay must release, and an upper current (cell illuminated) above which the relay must operate.

The details of Fig. 3 have been redrawn in Fig. 4 and the lower curve OY, corresponding to ambient illumination of the cell, has been added. Since operation is now confined within the area CLMK, the maximum and minimum limits of current are OG and ON respectively.

Line EQF represents the nominal resistance of the load (i.e. the relay coil) at the nominal supply voltage OF.

To allow for variations between individual cells, it is advisable to specify a relay "operate" current OS, say 20% lower than that corresponding to K, and a "release" current OT, say 20% higher than that corresponding to L. The ratio of OS to OT should be at least two to one for reliable operation. A lower ratio indicates insufficient differential between the control illumination and the ambient illumination. This may be remedied by increasing the output of the light source.

If it is desired to use an existing supply voltage, the minimum load line may be drawn tangential to the dissipation curve from a point corresponding to the upper limit of this supply voltage. Inspection will then show whether operation at this supply voltage is practicable.

Similarly, if it is desired to use an existing relay, the appropriate load line may be drawn tangential to the dissipation curve and the corresponding operating points determined. In this case, the minimum predicted control current (cell illuminated) must be greater than the operating current of the relay; similarly, the maximum predicted "ambient" current must be less than the relay release current.

Finally, a check must be made to ensure that the relay current and voltage ratings specified by the manufacturer are not exceeded under any of the possible operating conditions of the circuit.

In practice, it is advisable to make part of the load variable, thus providing a sensitivity control and a means of compensating for variations between individual cells.

Where wide variations in ambient illumination are likely to cause false operation of the relay, a bridge circuit may be used. Two photoconductive cells, both exposed to ambient illumination but only one of which is exposed to the control illumination, provide two arms of the bridge. The other two arms consist of resistors, one of which is made variable so that the bridge may be balanced in the absence of control illumination. A sensitive relay may be operated by the unbalance voltage appearing across the diagonal of the bridge. In this case, all the above design considerations apply, the ratio arms of the bridge being regarded as the load resistors for each cell as in Fig. 5.

An example of a simple practical circuit of a light operated relay using a CdS cell is shown in Fig. 6.

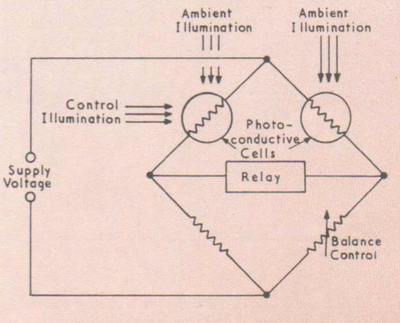


Fig. 5. Compensation for ambient illumination by means of a bridge circuit.

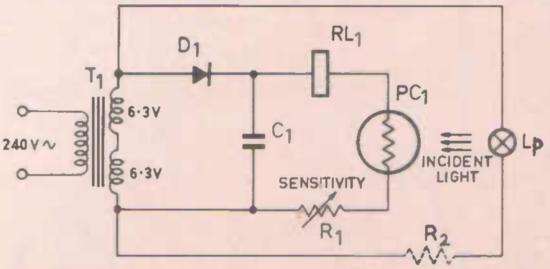


Fig. 6. Simple practical circuit of a light-operated relay using CdS cell. The relay operates when an intervening object breaks the beam of light normally passing from lamp to cell.

Parts List

R_1	500 Ω pot., ww.
C_1	100 μF Philips Type C435AL/G100.
D_1	Philips Type OA210.
PC_1	Philips Type ORP30.
T_1	240 V/6.3 V + 6.3 V, 3.0 A, e.g., Ferguson Type PF162.
L_p	12 V (power dependent on distance of lamp from cell). Lamp life may be considerably increased by operating at lower voltage with series resistor R_2 (shown dotted).
RL_1	Series 3000 telephone type relay (resistance 500 Ω; pull-in current 10 mA; drop-out current ≤ 3 mA).

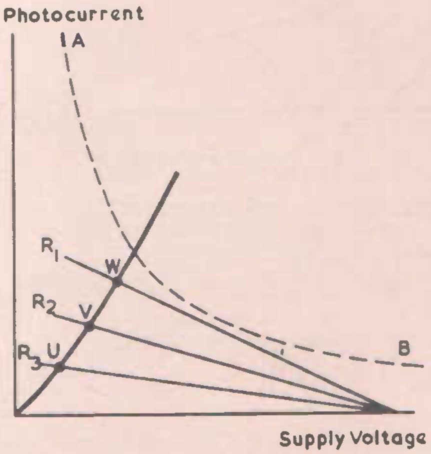


Fig. 7. Graphical construction of an illumination level curve using values of current measured with three different values of load resistance.

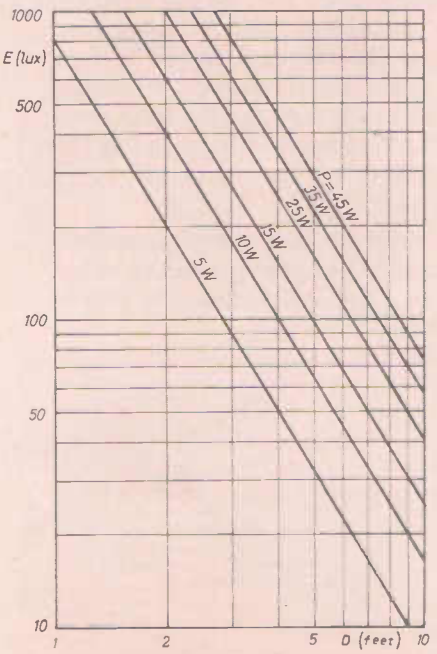


Fig. 8. Direct illumination in lux (E) at a surface distance (D) in feet from several low-powered incandescent lamp sources.

Use of Photoconductive Cells with Amplifiers

If the level of control illumination is very low, it may be necessary to use an amplifier following the photoconductive cell. For circuits in which a voltage variation is required, such as vacuum tubes, thyratrons, and trigger tubes, the supply voltage and load resistance should be high in order to give a large voltage swing for a given change in illumination. Where current swing is required, such as in the base circuit of a transistor, the voltage and load resistance should be low.

Flame Failure Control

In this application the previously mentioned lower limit of current is important, particularly if the cell is exposed to light radiated from hot fire-bricks after the flame has failed. For direct operation of a relay use the highest possible incremental sensitivity and then reduce the illumination level at the cell by means of a filter until such time as the "dark" current falls to an acceptable level.

Determination of Illumination Level

Quite frequently the operational illumination level (plotted in lux on the curves) will be an unknown quantity. The approximate level in a practical case may be quickly checked with an average photoconductive cell of the type to be used. Select a convenient supply voltage and use a variable resistor with a minimum value sufficient to ensure that the cell dissipation will not be exceeded. Measure the cell current at three known values of series resistance R_1, R_2 and R_3, and plot the results as shown at points U, V and W in Fig. 7. The line joining these points will be the illumination level curve.

ASSOCIATED EQUIPMENT

Light Sources

CdS cells may be used with various sources which emit radiation in the visible or near infra-red part of the spectrum—such as daylight, fire or metals at high temperatures. However, where a light source for general applications has to be found, a tungsten filament lamp is ideal.

For distances up to a few feet between a tungsten-filament lamp and a CdS cell it is often possible to use direct illumination without lenses or reflectors. An indication of a suitable source may be obtained from Fig. 8, which shows illumination (E) in lux as a function of distance (D) in feet from some low-powered incandescent lamp sources, each having an assumed efficiency of 15 lumens per watt. Low-voltage lamps, such as automobile headlamps, are suitable sources. The values of illumination given in Fig. 8 are fully applied to the cell only when light strikes its sensitive surface at right angles. It is also assumed that no reflectors, lenses, masks or filters are used.

Increased illumination of the cell may be obtained by the use of lenses or reflectors. Lens systems are generally necessary when the distance between source and cell exceeds a few feet, or where the light is filtered or passed through a slit in a mask. Care must be taken that the cell is not placed exactly at the focus of the beam, as this would result in local damage to the sensitive area.

Power Supplies

For the average application a simple low voltage power supply will be adequate. For AC circuits, a filament transformer with 6.3 V or 12.6 V windings may be used. For DC circuits, silicon diodes in half-wave or voltage doubler configuration are suitable. Voltage regulation curves for silicon diode rectifiers have been published in a previous issue of the Digest.(1)

(This survey has been compiled by D. J. Hancock of the Miniwatt Electronic Applications Laboratory.)

References

1. Hancock, D. J., & Heins, P., Fundamental Facts about Rectifier Ratings, *Miniwatt Digest,* Vol. 1, No. 1, pp. 2-6.
2. Summer, W., Photosensitors, Chapman & Hall, 1957. (Contains over 2,500 further references).

Valve News

This is the second of two articles and describes Design 2 for a two-stage IF amplifier for TV receivers

IF Amplifier Using Single-Tuned Transformers

This amplifier is a single-tuned version of the two-stage IF amplifier described in the preceding issue of the Digest (Vol. 1 No. 8). The reader is referred to that article for a general discussion of the relative merits of the double-tuned versus single-tuned interstage coupling.

Circuit Description

The design basis for the amplifier (Fig. 1) is the theory for a flat stagger-tuned system. This theory and design applications may be found in the literature(1, 2, 3). The design yields data for four stagger-tuned circuits. Two of these arranged as a bandpass transformer L_1 L_2 at the amplifier input, and the remaining two circuits are in the form of bifilar single-tuned transformers T_1 and T_2 which serve as interstage and output coupling elements respectively. From the design, each tuned circuit is assigned a specific tuning frequency and bandwidth, and the position of the transformers in the amplifier is determined by the maximum value of Q realisable in each stage. Where required, bandwidth is adjusted by means of damping resistors.

As explained in Part 1, the NT3009 tuner must be coupled to the amplifier using a bottom capacity coupled bandpass arrangement. The primary L_1 (in the tuner) is connected to the secondary L_2 via a length of coaxial cable. The coupling capacitance plus a fixed ceramic capacitor **C**, has to be 68 pF total. **C** should be mounted, with short leads, at the tuner output terminal. In this case, in order to realise the required primary Q, the resistor R must be disconnected by severing the wire loop in the tuner, accessible through the cover-plate. The inherently poorer selectivity of single-tuned circuits as compared with double-tuned circuits was discussed in the previous article. It is therefore obvious that the degree

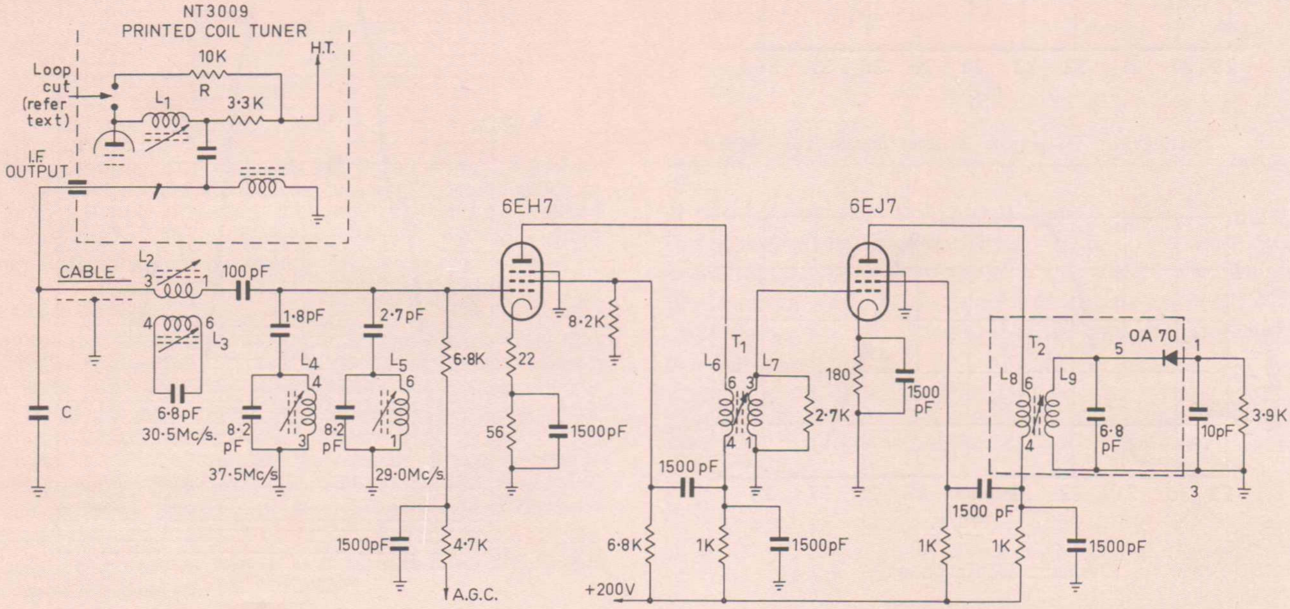


Fig. 1. Circuit diagram of two-stage IF amplifier with single-tuned transformers.

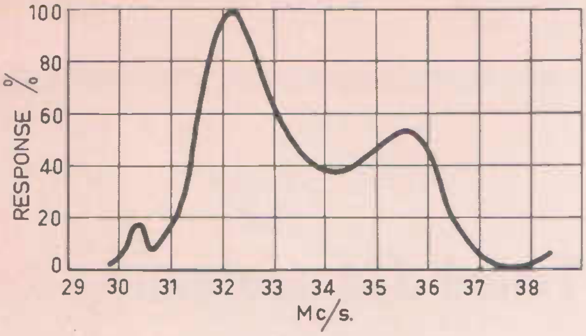
of adjacent channel suppression will depend to a greater extent on the performance of the trap circuits.

As in the previous design, all traps are situated at the input of the amplifier. Bridged-T traps were investigated, but their performance was considered unsatisfactory. Although very good attenuation can be achieved at the trap resonant frequencies, the suppression band is very narrow and the amplitude of re-entrants is high. Normal trap circuits are more satisfactory in this regard, whilst maintaining adequate adjacent channel rejection. The associated sound trap is an absorption type, being inductively coupled to L_2.

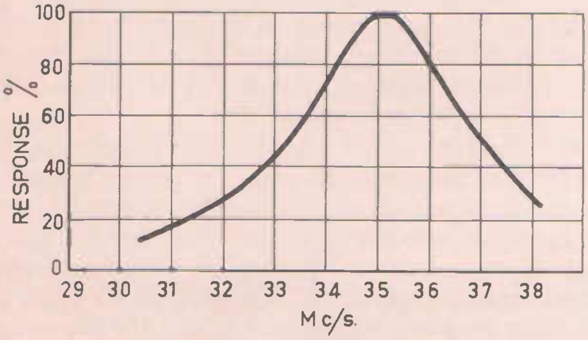
The screen of the 6EH7 is held relatively constant at 90 V, resulting in a rather steep control characteristic which permits the mutual conductance of the valve to be reduced by a factor of 100 when the bias is changed from 0 to —9 V. The required control characteristic depends upon the AGC amplifier and would be adjusted to suit the particular circumstances.

In the actual amplifier, some small deviations were made from the provisional calculated response. The latter provides a good starting point for construction; however, it will usually be necessary to slightly modify some circuit parameters to take into account influences such as trap circuits, lay-out and shape of the vision carrier slope. However, such modifications should be kept to a minimum, since major deviations will result in appreciable reduction in maximum gain.

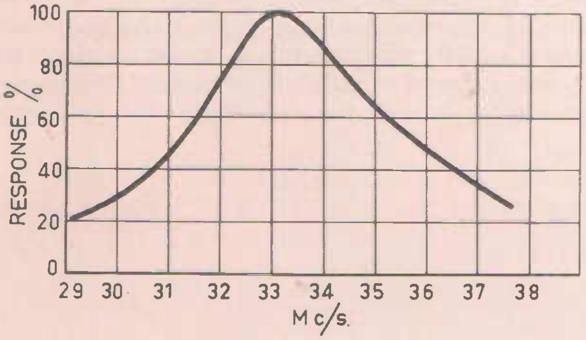
Fig. 2 shows the swept characteristic of each individual stage. The measurements were made using a low impedance detector probe. The overall response



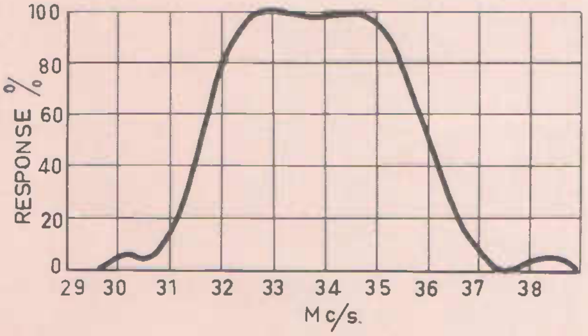
TUNER + IF INPUT BANDPASS TRANSFORMER (L_1 L_2) + TRAPS



DETECTOR BANDPASS TRANSFORMER T_1



INTERSTAGE BANDPASS TRANSFORMER T_2



OVERALL IF RESPONSE

Fig. 2. Frequency responses of individual stages and overall response.

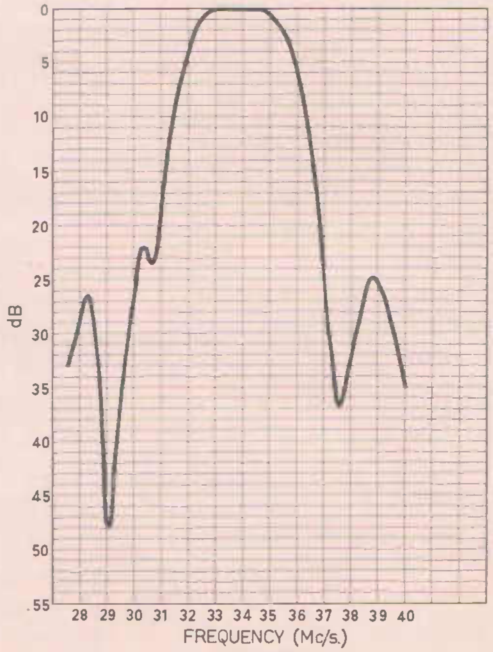


Fig. 3. Overall IF amplifier response for —1 V DC at detector and —5.0 V bias.

(also shown in Fig. 2, but inverted) was measured between mixer grid (tuner in blank channel position) and the video detector output, with a bias voltage of —5 V on the 6EH7. The output of 5 V peak to peak was taken through a 100 K Ω isolating resistor.

A curve representing the overall IF response, measured point-by-point using a signal generator, is shown in Fig. 3. The input to the mixer grid was adjusted to keep the vision detector output constant at —1 V DC. Adjacent channel rejection is seen to be 48 dB (vision) and 37 dB (sound).

Gain

The gain of the IF amplifier at 33.5 Mc/s (from the control grid of the 6EH7 at zero AGC through to the detector) was measured to be 55 dB, i.e., 1.78 mV input for 1 V DC output. With a minimum tuner gain of 37 dB the overall gain from aerial to video detector is 92 dB or 25 μV input for 1 V DC output. It will be appreciated that the gain specified for the tuner is conservatively rated due to measurement techniques and in practice higher gain figures may be expected.

Alignment

Spot alignment is carried out by inserting an unmodulated signal at the mixer control grid of an amplitude sufficient to give 0.5 to 1 V DC at the vision detector load resistor. The DC voltage is measured with a VTVM through a 100 K Ω isolation resistor and —5 V bias is applied to the 6EH7. Then the IF coils are tuned in the order shown by adjusting them to the corresponding tuning frequencies.

Coil	*Adjustment*	*Tuning Frequency (Mc/s)*
L_3	for min. output	at 30.5
L_4	for min. output	at 37.5
L_5	for min. output	at 29.0
L_8/L_9	for max. output	at 33.1
L_6/L_7	for max. output	at 34.9
L_1	screw core (outwards) until flush with former	
L_2	for max. output . . . . —then connect damping network (100 Ω in series with 1000 pF) between control grid of 6EH7 and ground	at 33.5
L_1	for max. output	at 33.8

It is recommended that there should be no serious departure from the given tuning frequencies, since this would result in loss of gain. After alignment, the amplifier should be checked for stability at zero bias. There should then only be a slight change in the shape of the overall response curve.

Coil Construction

Constructional details of all coils are given in Fig. 4. Note that both bifilar transformers T_1 and T_2 have turns ratios differing from unity. The coils were designed for "capacitance matching"(2, 3) taking into account the differences between valve input and output capacitances. This yields a slight gain improvement. If it is desired, for reasons of ease of manufacture, to employ transformers of unity turns ratio, then small changes of circuit constants will be necessary, such as different damping resistance values.

All coils are wound on "Aegis" coil formers housed in a ¾" sq. aluminium shield can.

General Construction

The remarks about lay-out and wiring in the previous article also apply to this amplifier.

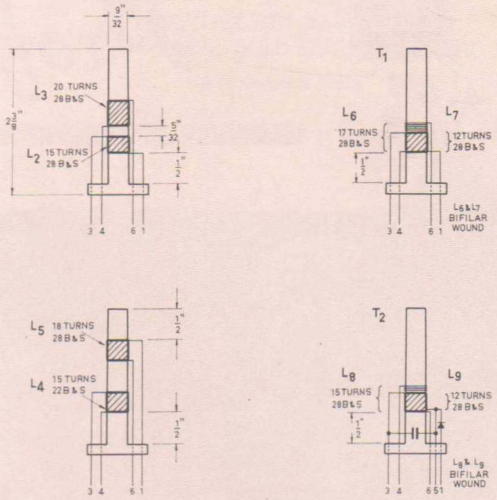


Fig. 4. Constructional details of coils.

Conclusion

The two-stage IF amplifier with single-tuned transformers described above and the amplifier with double-tuned transformers described previously were built to compare their respective performances, and also to determine the overall gain which may be expected in a combination of the new tuner NT3009 with a two-stage IF strip. Comparative figures are given in Table 1.

TABLE 1

Transformer	IF gain (dB)	Overall gain (dB)	Adj. Channel Rejection (dB)	
			Vision	Sound
Single-tuned	55	92	48	37
Double-tuned	60	97	50	45

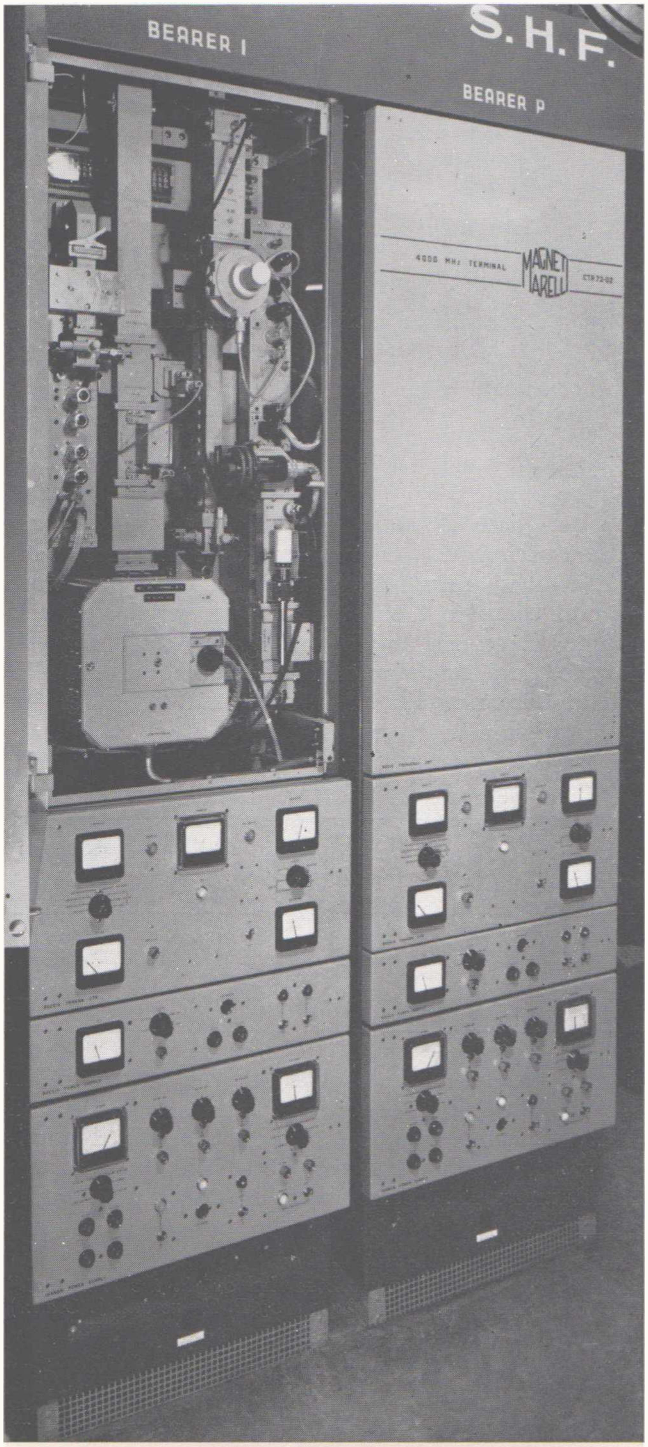
It can be seen that the overall gain is adequate for all but extreme fringe conditions. The extra gain and adjacent channel rejections of the double-tuned amplifier is achieved at the cost of greater precision in transformer manufacture and more complex alignment techniques.

(This article is based on work carried out in the "Miniwatt" Electronic Applications Laboratory by P. Heins and J. Clark.)

References

1. A. G. W. Uitjens, T.V. Receiver Design, Monograph I, IF Stages, Philips Technical Library, 1953.
2. J. S. Singleton, Stagger-tuned and Bandpass-coupled Circuits in Wideband IF Valve Amplifiers, *Mullard Tech. Comm.*, Vol. 5, No. 42, Feb. 1960, pp. 48-59.
3. D. G. Fink (ed.), TV Engineering Handbook, McGraw-Hill, 1957, Chapters 12 and 16.

Professional Tubes



Photograph of microwave relay equipment providing 960 telephone circuits or one television channel, installed at Sydney by the Postmaster-General's Department.

4000 Mc/s Disc-seal Triodes

Philips EC157 and EC158

The introduction by Philips⁽¹⁾ of the "L" cathode has been an important factor in the attainment of the high status of the microwave triode amongst tubes of more complex construction or operation. Further improvements⁽²⁾ in this cathode technique have led to the introduction of two new power triodes (EC157 and EC158) which are ideally suitable for the 4000 Mc/s microwave relay band. A 4000 Mc/s amplifier is described having a 0.1 dB bandwidth of 50 Mc/s which is sufficient for the transmission of a single TV channel or some hundreds of telephony channels. Phase distortion, associated with fall-off in amplitude response, or arising from group delay times within the amplifier, is negligibly small.

The EC157 and EC158 are disc-seal triodes designed for operation as broadband amplifier tubes at frequencies in excess of 4000 Mc/s. The electrodes of the EC158 are of larger diameter, and as a consequence it has a higher maximum permissible cathode current and a higher permissible anode dissipation. Both types are suitable for use as low level amplifier, frequency multiplier or output tube in microwave radio link transmitters. Other applications include use as a low-noise pre-amplifier at frequencies below about 1000 Mc/s, highly stable cavity local oscillator, mixer, limiter, and high level anode bend detector. Such applications have been described by Gieles.⁽³⁾

The disc-seal construction permits ready insertion in coaxial or waveguide circuits. At UHF and higher frequencies the grounded grid configuration is favoured due to the degree of enclosure of the electromagnetic field afforded, and due to the substantial reduction in feedback capacitance. In the case of the EC157/EC158 the particularly small reaction admittance (represented by anode-to-cathode capacitance, the effective inductance of the grid wires and electronic feedback) enable extremely stable grounded grid stages to be constructed. Such a circuit is described below.

PMG Radio Bearer Equipment Employing EC157

The photograph of this equipment (in which a cover has been removed in order to display the RF section) depicts the EC157 cavity in the upper right portion, with the output stage employing a Philips travelling wave tube type 55340 towards the lower left (square shaped assembly). A more detailed illustration of the EC157 cavity is given on the front cover.

The EC157 operates as a sixth harmonic multiplier from an input of the order of 150 mW supplied by a crystal multiplier strip. It is incorporated in the receiver section as the output stage of the local oscillator. The EC157 input circuit is of radial construction and connects to the crystal multiplier via coaxial cable. The output circuit on the other hand is constructed in waveguide and connects to a filter, also in waveguide, and thence via a coaxial to waveguide transition and coaxial cable to a balanced mixer. The received signal arrives at the mixer from the aerial via waveguide components comprising branching filter, isolator, bandpass filter and matching transformer. The output of the mixer provides the 70 Mc/s IF.

Design Considerations

The design of both the EC157 and EC158 is centred on a reduction of the three basic factors which limit the performance of the triode tube at microwave frequencies, i.e., transit time effects, "parasitic" influences and increased losses.

(*a*) *Transit time effects (and the influence of the "L" cathode)*

When the period of a high frequency signal is no longer large compared with electron transit time from cathode to anode, a phase shift is introduced between control voltage and anode current. This decreases the effective mutual conductance and introduces appreciable input circuit damping.

In order to obtain a short transit time, the spacing between grid and cathode should be small and the current density high. Consequently a g/k separation of 40μ (with heated cathode) was adopted for the present design together with an "L" cathode which permits a continuous current density of approximately five times that of a conventional oxide-coated cathode.

(*b*) *"Parasitic" influences*

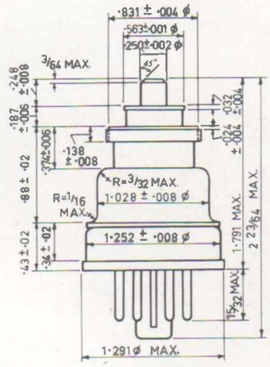
Interelectrode capacitances and lead inductances introduce feedback at high frequences which affects the stability, and might even cause instability.

Lead inductances have been reduced to negligible proportions in the EC157/EC158 by the use of disc structures for the electrode connections. In a grounded-grid circuit, some small effective inductive coupling provided by the grid mesh itself constitutes practically the whole of the inductive coupling between anode and grid circuits.

The parallel-plane electrode construction permits the use of relatively small electrode areas, with resulting

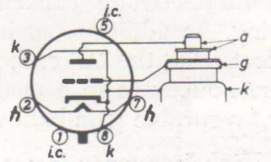
PHILIPS EC157 and EC158
4000 Mc/s DISC-SEAL TRIODES

(Abbreviated Data)



All dimensions in inches.

Octal Base
Grid Disc Threaded
7/8" — 32 NS-2B



General Electrical Data	EC157	EC158	
Heater voltage	6.3 ± 2%		V
Heater current	0.735	0.90	A
(No cathode pre-heating required)			

Direct Interelectrode Capacitances ($V_f = 6.3$ V, $I_k = 0$)	EC157	EC158	
Anode to grid	1.4	1.7	pF
Anode to cathode	0.035	0.036	pF
Grid to cathode	3.0	3.5	pF

Maximum Ratings (Absolute Maximum)	EC157	EC158	
Anode voltage ($I_a = 0$)	500		V
Anode voltage	300		V
Anode dissipation	12.5	30	W
Cathode current	70	170	mA
Grid voltage (negative)	50		V
Grid current	10	25	mA
Grid dissipation	200	350	mW
Driving power*	1	2	W
Heater to cathode voltage	50		V

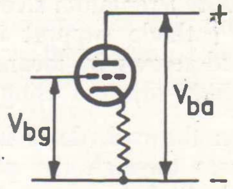
* in a grounded grid circuit at 4000 Mc/s

Operating Conditions as Amplifier at 4000 Mc/s

(Mechanical Circuit Described in Text)

	EC157		EC158	
Anode Supply Voltage (Vba)	200	200	200	V
Grid Supply Voltage (Vbg)	+20	+20	+20	V
Cathode Bias Resistor ..	[1]	[1]	[1]	
Anode current	60	30	140	mA
Bandwidth (0.1 dB) ...	50	50	50	Mc/s
Output power at 8 dB power gain	1.8	—	—	W
Output power at 6 dB power gain	—	0.5	5.3	W
Low level power gain..	13	13	11.5	dB

[1] A variable resistor of
max. 500 Ω at $I_a =$ 60 mA
max. 1000 Ω at $I_a =$ 30 mA
max. 200 Ω at $I_a =$ 140 mA
—in order to obtain desired I_a.



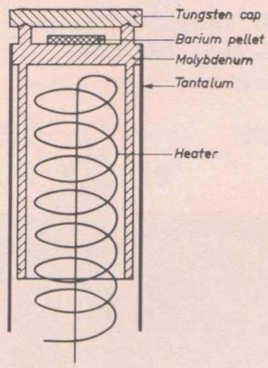


Fig. 1. Cross section of "L" cathode.

low interelectrode capacitances despite their close spacing. In addition, again despite the close spacing of electrodes, the "L" cathode provides a high ratio of transconductance to capacitance. The net result is a very favourable gain-bandwidth product.

(*c*) *High frequency losses*

These normally comprise dielectric losses in envelope and spacers, dissipative losses in electrodes, and losses due to "skin effect".

In the case of the EC157/EC158, dielectric losses are kept small since no spacers are used, a special low-loss glass envelope constituting the only dielectric material.

Silver-plated electrode connections reduce circuit damping arising from "skin effect".

CONSTRUCTIONAL DETAILS

The Cathode

Details of the "L" cathode are given in Fig. 1. The main cathode member consists of a molybdenum tube provided with a partition, so that two compartments are formed. The smaller (upper) compartment contains a pellet of barium compound and is closed by a cap of porous tungsten. The lower compartment houses the heater. Since the "L" cathode is operated at a relatively high temperature, the space between the inner wall of the tube and the heater is fully occupied by aluminium oxide to avoid excessive heater temperatures (and consequently reduced life expectation). Aluminium oxide is characterised by both excellent electrical insulation and thermal conductive properties.

In order to provide the required thermal insulation between the cathode and its support, a thin walled (0.0005") tantalum sleeve is used to connect the two. The cathode support is mounted by three spring-loaded screws by means of which the g/k spacing is precision adjusted using an optical technique.

When the cathode is heated, the barium compound diffuses through the porous cap, at the surface of which it forms an extremely thin layer of active emitter material. The thickness of this layer is so small that the cathode surface can be regarded as being metallic, so that it presents less losses than would the semiconductive coating of oxide-coated cathodes. Moreover, the solid metallic surface with the thin emissive layer permits close tolerances in the distance between cathode and grid.

Barium, which evaporates from the cathode surface, is replenished by the supply in the upper cathode compartment. This feature makes the "L" cathode comparatively insensitive to current surges, poisoning, etc., because only the small amount of barium present in the emissive layer is affected.

The Grid

The grid is composed of tungsten wire wound on a molybdenum frame. After winding, the wires are brazed to the frame by means of gold. During this process the wires themselves are gilded.

Owing to the high temperature of the "L" cathode, and the small g/k spacing, the grid wires reach a high temperature. This is in fact beneficial in that it considerably reduces the formation of barium deposits on the grid wires. In fact the diameter of the wire is so chosen that the barium evaporates from the wires almost as fast as it arrives from the cathode. Grid emission, at the high grid temperature, is adequately suppressed by the gilding of the wires.

After the gilding operation, the grid frame is extended, so as to stretch the wires in order to maintain tension when hot. To ensure correct tension, the mechanical resonant frequency of each wire is checked after being caused to vibrate by the application of an electric field.

A small cylindrical shield is connected to the grid disc in order to screen the upper part of the cathode, and so prevent precipitation of barium on the inside of the glass envelope.

SUPPLY CONSIDERATIONS

Anode Supply

The EC157/EC158 has been designed for a low anode voltage of 180 V. However, according to the recommended DC circuit (refer to tabulated data) the actual anode supply voltage is some 20 V higher, resulting from the drop across the relatively large cathode resistor. Such a value has been recommended in order to obtain effective stabilisation of the cathode current. As a consequence, the tube can be replaced without readjusting the anode current.

An unstabilised anode supply can be used provided mains fluctuations are normal, and amplitude-to-phase conversion caused by the normal ripple on the anode supply is also negligible.

Heater Supply

In order not to disturb the sensitive equilibrium between evaporation and diffusion of the barium, it is necessary to maintain the temperature of the "L" cathode within relatively narrow limits. The permissible tolerance in heater voltage is therefore 2% maximum. A transistorised regulator suitable for such an application will be described in the next issue of the *Digest*.

Grid Supply

The stabilising action of the cathode resistor is lost when the grid supply voltage is not highly constant. Therefore this voltage should be well stabilised. Since the current required of the grid bias source is very small, it can be made up of a voltage-stabilising tube, fed from the anode-supply voltage.

LIFE EXPECTANCY

When used within the published ratings, the EC157 and EC158 are guaranteed for 6000 hours operation (individual tubes) or 10,000 hours operation (average of 100 tubes)—at frequencies up to 4200 Mc/s.

The life of the tubes is assumed to have elapsed when the characteristics have reached the "life test end points" which are:

EC157: Output power $\leqq$ 1 W at a power gain of 6 dB.
Power gain $\leqq$ 8 dB at a driving power of 1 mW.

EC158: Output power 2.5 W at a power gain of 4 dB.

freq. = 4200 Mc/s.
heater voltage = 6.3 V ± 2%.
anode voltage = 180 V.
anode current = 60 mA.
bandwidth (0.1 dB down) = 50 Mc/s.

EXAMPLE OF USE AS A 4000 MC/S GROUNDED GRID STAGE

The amplifier described below can be equipped with the EC157 or EC158. The figures of power gain and output power at a 0.1 dB bandwidth of 50 Mc/s as given in tabulated data are the results of measurements on this type of amplifier.

Construction

Fig. 2 depicts an assembled amplifier whilst Fig. 3 shows two cross sections of the amplifier.

As may be seen from these figures, the input and output connections are formed by waveguide sections. The two waveguides are separated by a partition, into the horizontal part of which is screwed the grid disc. The cathode circuit is formed by the short-circuited rear section of the input waveguide. The anode circuit (the primary resonant circuit of the output bandpass filter) consists partly of a radial and partly of a coaxial cavity, the whole being tuned in $\frac{\lambda}{4}$ mode by means of a piston in the coaxial section. The piston is of the Σ type and makes contact only with the outer conductor of the coaxial line, a toroidal spring located within the piston groove providing fully effective RF contact.

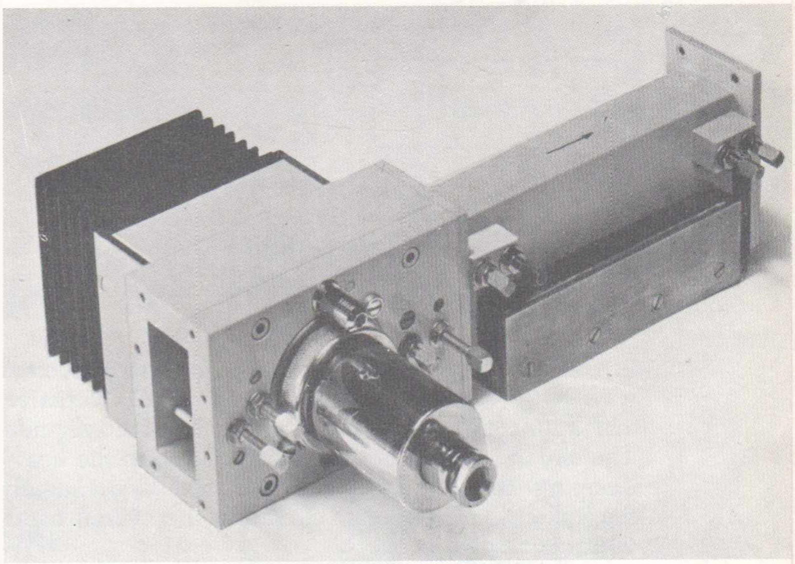


Fig. 2. Photograph of the 4000 Mc/s amplifier with heat radiator and ferrite isolator.

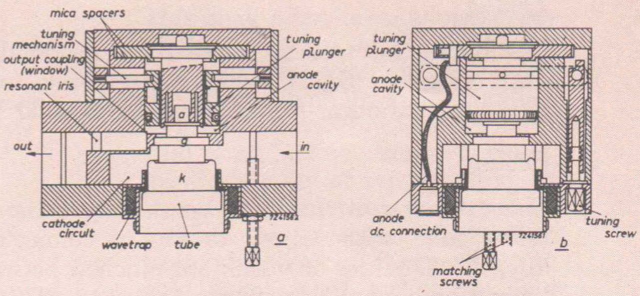


Fig. 3. Cross sections of the 4000 Mc/s amplifier.

The output coupling is formed by a window in the radial cavity which opens into the output waveguide. In the narrow part of this waveguide is located a resonant iris composed of two inductive posts and a capacitive screw: this forms the secondary tuned circuit of the output bandpass filter.

The cathode shell of the tube is insulated for DC from the underside of the input waveguide. However, "choke coupling"(4) has been used in order to provide RF continuity.

At the high frequencies in question, the equivalent resistance of the tube between cathode and grid disc is different from that at low frequencies. An equivalent circuit for the input inpedance of the tube is shown in Fig. 4. Here R_{GK} is the input resistance, measured directly between actual grid and actual cathode and C_{GK} is the capacitance between these electrodes, whilst L_K is the inductance of the cathode base and cathode disc. C_D is the capacitance between grid disc and cathode disc. At 4000 Mc/s this circuit

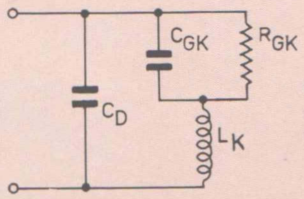


Fig. 4. Equivalent circuit for the tube input impedance when connected in a grounded grid configuration.

in conjunction with a short length of short-circuited waveguide becomes approximately purely resistive, and approximately matched to the input waveguide. The circuit exhibits broad resonance due to the heavy damping imposed by this resistance. Consequently the influence of the input circuit on the overall bandwidth is negligible.

For the purpose of matching, inductive posts and capacitive screws are introduced in both the input and output waveguides.

Tuning

The tuning mechanism allows for a piston displacement of about 5/32″, which corresponds to a frequency variation of from 3700 Mc/s to 4500 Mc/s.

Cooling

The extension of the inner conductor of the coaxial line ("cold" with respect to RF) is connected to a disc, the flat sides of which are pinched between the body of the amplifier and the top plate. This disc is insulated by means of thin mica washers in order to combine good heat transfer with DC isolation.

When the tube is used at anode dissipations exceeding 15 W, an external heat radiator has to be employed. Such is portrayed in Fig. 2 which includes both a fitted radiator (left rear) and a ferrite isolator (at right).

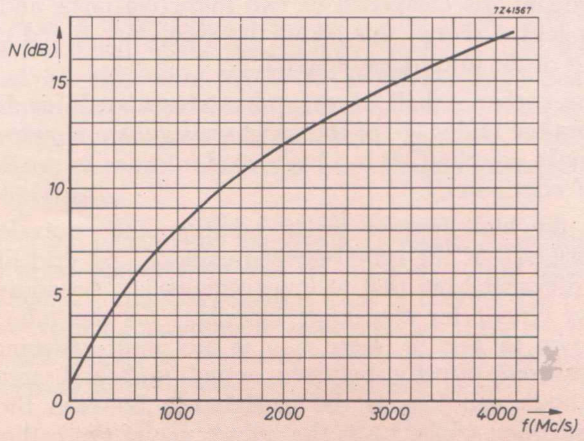


Fig. 5. Minimum noise figure (N) of the EC157.

Heater and Cathode Connections

These are obtained via a multi-lead cable terminated in a standard Octal socket which is connected to the tube base and secured to the "choke coupling" by means of a cap nut.

NOISE FIGURE

Although the EC157 is primarily intended for use as a power amplifier tube, its favourable noise properties may also be exploited in pre-amplifier stages, especially at frequencies below 4000 Mc/s.

The minimum noise figure of the EC157 as a function of frequency is plotted in Fig. 5.

AVAILABLE ANCILLARY EQUIPMENT
(and Complete Units)

In order to reduce the reaction from the input of an amplifier, or antenna, on the output of a preceding stage (which occurs as a result of unavoidable mismatches) ferrite isolators can be supplied for adaptation to a wide range of standard waveguide.

Besides the amplifier block herein described which is available as type No. B8 733 00, the block can be supplied with heat radiator (type K3 995 12) the assembly being then designated B8 733 01. Furthermore, to allow for the possibility of parallel operation of output stages, suitable waveguide joints are available.

FURTHER INFORMATION

For those requiring further details of applications of the EC157/EC158, information is available on request.

However, for a general review of fundamentals concerning the EC157 and related Philips disc-seal triodes (either in production or in development) the reader is referred to reference 3, which in turn lists a number of further references.

References

1. H. J. Lemmens, M. J. Jansen and R. Loosjes, A New Thermionic Cathode for Heavy Loads, *Phil. Tech. Rev.*, Vol. 11, 1949/1950, pp. 341-350.
2. A. Venema, Dispenser Cathodes, *Phil. Tech. Rev.*, Vol. 19, 1957/58, No. 6, pp. 177-190.
3. J. P. M. Gieles, Applications of Microwave Triodes, *Phil. Tech. Rev.*, Vol. 22, 1960/1961, No. 1, pp. 16-28.
4. G. L. Ragan, Microwave Transmission Circuits, Radiation Laboratory Series, No. 9, McGraw-Hill, New York, 1948.

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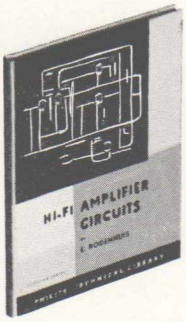

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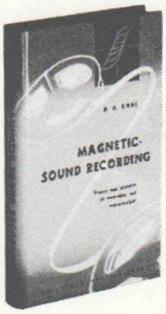

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