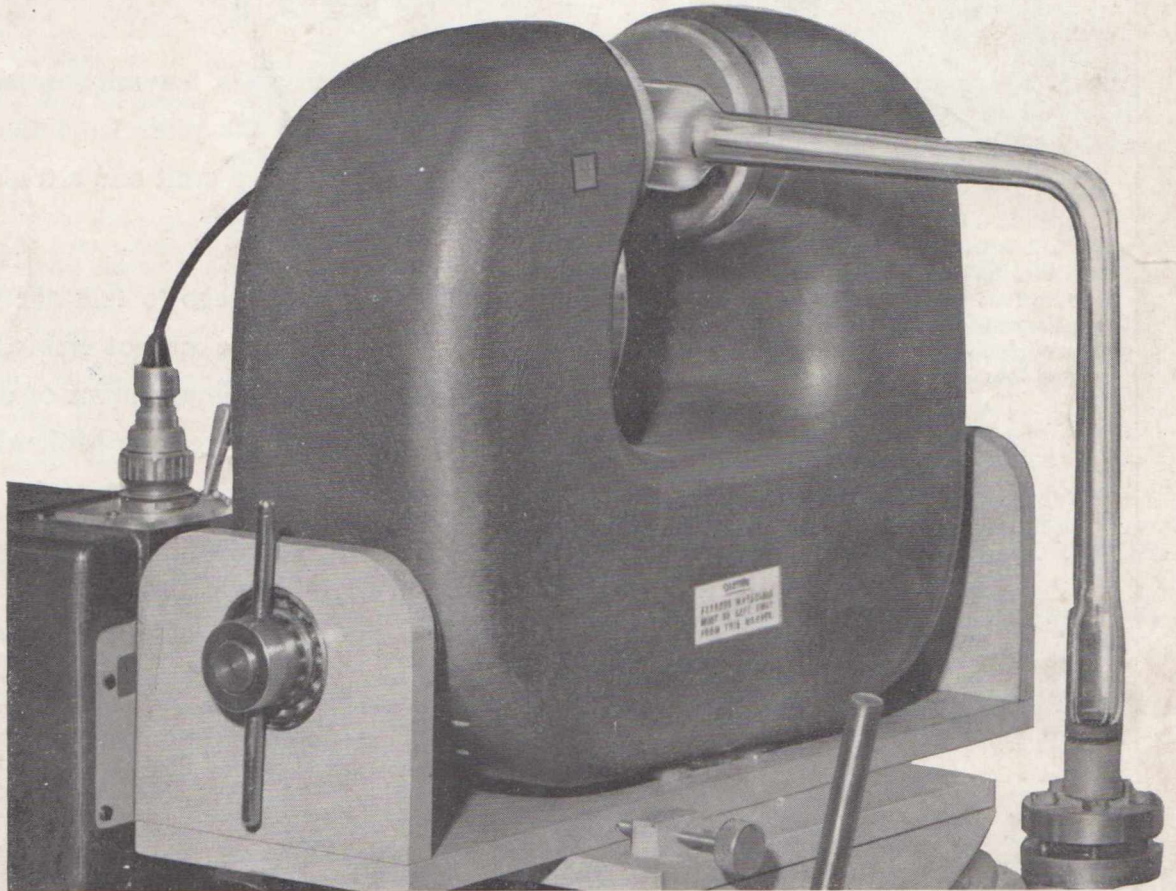


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The Vacuum Pumping system shown on the front cover utilises a Mullard Omegatron which is a simple form of mass spectrometer, providing a means of analysing the residual gases and vapours in vacuum systems. It can also trace the evolution of gases within a sealed-off system, the action of getters and the permeation of glass and other materials by various gases. For a brief description of the Omegatron, see page 56.

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*"Oh, wad some Pow'r the giftie gie us,
To see oursels as ithers see us."*

Robert Burns.

The Insignia and the Image

Both noticed by the other fellow and always linked—the image more elusive with pulse and personality, for it can surge with the progress of the company, by its products and its personnel, its aggressiveness and its humility, by its Service—or wither for the lack of it!

An insignia, perhaps a few minutes work by an artist, an image evolved through the years from the painstaking efforts of a dedicated team with a craft and a tradition to be nurtured and preserved.

Humility softens our ego to talk about a Mullard image, whatever it may be, but we are not unmindful of the key—the continuity and ever-expanding support of our customers, for it is you—our readers—who see the Mullard image.

M.A.B.

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VIEWPOINT WITH MULLARD

HOW REMOTE, REMOTE?

Near 16 feet, if it be remote control of a television receiver and maybe 16 million miles for a space vehicle!

Much of mankind's inventiveness has been directed to leisure and for ease of control and often remote, be it the harness reins of a horse and cart or more recently, the controls of a television receiver.

Requirement

At this time, rather than set out a specification of what form a control device might take, it is as well to decide just where remote control fits into the picture, how useful it might be and whether it is a gimmick or of practical value. The answer is self-evident in that a remote control device with channel selection and ancillary facilities such as brightness, contrast and volume are certainly worthwhile and particularly attractive to the existing owners of television receivers, more particularly, to the "constant viewers."

Obsolescence

Having undersold the 17", 21" 90° and 21" 110° market, apart from cabinet styling and presentation, remote control is perhaps the only worthwhile obsolescence factor to encourage the sale of new television receivers. Moreso because of the wider programme scope with the additional channels coming into service, some overlapping and some with useful fringe coverage, for example the third commercial channel in some Metropolitan areas; and Sydney to have four local stations and four with a useful signal level from outside the area.

It has been suggested that 45% to 50% of the new TV receivers sold in the Metropolitan areas of Sydney and Melbourne in the year 1962/63 will be against a traded-in receiver and, whilst many of these will be 17" and the early 21" receivers, the motive of remote control as a sales feature cannot be neglected.

It can also be supported that the few purchasing a television receiver for the first time are leaning towards remote control with the philosophy of "waiting for the latest developments."

Demonstrate in the Home

In a recent survey made with a group of Metropolitan retailers, each volunteered that remote control television was best demonstrated in the home, with all of the household present, when the first "gimmick" impression is soon dissipated and the practical benefits are readily appreciated. It would be naive of us to remind retailers that here is an article "to sell up to" and make a larger profit margin. Nevertheless, it is a very true one for the profit-conscious retailer.

The Ultimate

In appraising the ultimate as a requirement, it would no doubt be a cordless remote unit and these are available in one or two forms—ultrasonic keys and small radio-bearer transistorised units, but both somewhat costly, when the other factors such as brightness, contrast, volume, between-channel muting and so on are considered. Nevertheless, with the present stage of the art and local production costs, it would appear that remote control units, with cord, are a reasonable compromise for the time being at any rate.

Additional Advantages

Apart from channel selection and the adjustment of picture brightness and so on, the ability to mute some of the less tuneful and jarring theme music is an added sales feature and these points have already been well covered by the manufacturers of remote control television receivers.

Remote Control of Radiograms

Sound reproduction has reached a fine level of technical achievement but surely here is the ideal unit to apply remote control.

Concert Illusion

This Writer has always considered that half of the pleasure of record reproduction was to have the loudspeaker at one end of the room and the player and controls near the listener in that, not only can one control the level and bass and treble reproduction at the listening point, but the isolation of the loudspeakers inspires the imagination of remoteness in the concert hall or even intimate theatre.

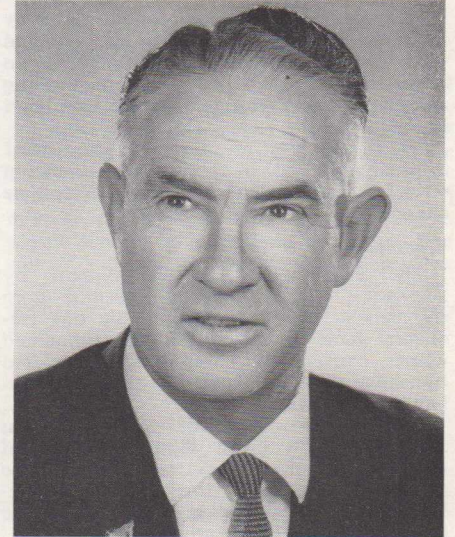
A Feature for Stereo

Striving once more for the ultimate, could it not be argued that a "must" for stereo is the adjustment of the channel balance at the listening point? We feel so—and with the knowledge of manufacturing costs and familiarity that receiver manufacturers have in their development of remote control devices for television receivers, the adding of remote control for stereo radiograms is relatively straight-forward. Again, the same argument is applied in selling an article of higher unit value and larger profit margin.

We can picture the astute salesman weaving a sales story around the fact, that with a mixture of records on a record changer, some "loud" and some "soft", the listener can adjust the volume of each.

It is therefore not without enthusiasm, that we look at remote control of not only television receivers but also stereograms, as a vital factor in maintaining a satisfactory manufacturing and sales value level when exploiting the obsolescence factor.

MULLARD-AUSTRALIA PERSONALITIES



Mr. George A. Aungle

Mr. Aungle joined the Company in 1957 after a wide experience in Telecommunications, Broadcasting and Television. As a sales engineer in our Transmitting and Industrial Valve and Semiconductor Department, his activities are more closely linked to Government Departments and Public Utilities.

He is a member of the Institution of Radio Engineers Australia and served with the Royal Australian Navy.

Formerly a top-grade swimmer and water polo player, readers in Tasmania may be interested to know that he has, on several occasions, taken part in the classic annual Hobart event of swimming the Derwent.

Now, like many of his Mullard colleagues, he is a keen fishing and boating enthusiast, indeed we can now muster a flotilla.

OUTLOOK, 1963

To ensure delivery of your copies for 1963 please complete the form enclosed with this issue and mail today.



The Range of Mullard Transmitting Valves for SSB

The Table below has been compiled to acquaint designers with the range of Mullard transmitting valves available for SSB communication purposes and to facilitate the selection of suitable types for given applications. The figures in the Table are for frequencies below 30 Mc/s. The extent to which a valve may be used at higher frequencies with reduced output may be obtained from individual data sheets which are available on request. The data sheets should, of course, be consulted before commencing the design of new equipment.

Problems of selectivity, brought about by so many adjacent transmissions, coupled with selective fading, have resulted in an increasing number of station-operating authorities to investigate single sideband techniques.

SSB techniques are already being used to great advantage in special communication services and inter-continental telephone channels.

Transmission

The SSB method of transmission, by dispensing with one sideband, permits more channels to be established in any one frequency band than can be accommodated where conventional amplitude modulated transmissions with a carrier and two sidebands are in use.

Further advantages of SSB operation are that for a given input to the final amplifier a higher output is applied to the aerial; there is less distortion due to selective fading; and reception is less vulnerable to interference from unwanted stations.

Valves for SSB Operation

In an SSB transmitter, the operating conditions of the valves differ from those of an AM transmitter. It is essential that the RF stages should operate under strictly linear conditions, otherwise there will be an unacceptable level of distortion (inter-modulation products). In addition, high peak anode currents must be provided by the valves, preferably without grid current.

These requirements have been met by Mullard with eleven valve types which have characteristics suitable for SSB operation.

These types, with an outline of their performance, are listed in the Table.

The latest addition to the range of Mullard SSB transmitting valves is the QY5-800 which has been developed primarily for SSB systems. Investigation of the severe load distortion requirements has led to the adoption of control grid and screen grid geometry which provides a

valve characteristic with the required degree of linearity. It will be seen from the Table that this valve achieves both high power outputs and an unusually favourable figure of intermodulation distortion.

The operating conditions shown for each type refer to operation as a linear amplifier for SSB suppressed carrier service. Other details, such as the heater requirements, base connections and any special requirements regarding cooling may be found in the individual data sheets (Vol. 3 Mullard Technical Handbook).

The following operating notes apply to all the types in the Table:—

V_{g1} (the control-grid voltage) is adjusted so that the recommended anode current ($I_{a(o)}$), is obtained at zero signal.

$P_{load(driver)}$ is the power measured at the grid terminal of the amplifier valve and represents the power required from a driver stage to supply the required drive voltage and also to accommodate losses in the grid and grid circuits of the amplifier valve including damping, which may be required to make the load on the driver stage more linear.

$PEP_{(load)}$ represents the useful peak envelope power, assuming the circuit transfer efficiency to be approximately 85%.

$D_{i.m.}$ The voltage amplitude of all inter-modulation products is below the level shown which is referred to the amplitude of either of the two tone frequencies. Relative to PEP these figures will be increased by 6dB and are measured at full drive.



The QV08-100 is a typical Mullard SSB transmitting power tetrode and, with natural air-cooling, an output power of 220W (PEP) may be obtained.

LINEAR RF POWER AMPLIFIER, CLASS, AB₁ SSB SUPPRESSED CARRIER SERVICE

TYPICAL OPERATION AT f < 30Mc/s

'Two tone' modulation, max signal conditions

	QV06-20	QY3-65	QV1-150A	QV08-100	QY3-125	QV2-250B	QY4-250	QY4-400	QY5-500	QY5-800	QY5-3000A	
V_a	600	3000	1250	750	3000	2000	4000	4000	5000	4000	5000	V
V_{g2}	200	360	300	310	600	350	500	700	700	600	1000	V
V_{g1}	-42	-85	-45	-45	-108	-56	-93	-120	-90	-110	-117	V
$I_{a(o)}$	26	15	100	130	23	100	50	85	56	150	200	mA
I_a	72	45	180	270	77	190	115	180	180	330	380	mA
I_{g2}	5.0	1.5	4.4	26	7.0	4.0	3.0	5.0	15	40	25	mA
I_{g1}	0	0	0	0	0	0	0	0	0	0	1.5	mA
$V_{in(pk)}$	47	85	45	45	108	56	93	115	90	100	134	V
$P_{load(driver)}$	0.25	1.0	1.0	1.5	1.0	1.5	1.0	1.5	2.0	1.5	2.5	W
p_a	20	70	140	93	117	220	188	427	495	670	1115	W
p_{g2}	1.0	0.5	1.3	8.0	4.2	1.4	1.5	3.5	3.8	24	25	W
PEP (out)	46	130	172	220	228	320	454	586	810	1300	1570	W
$P_{out(mean)}$	23	65	86	110	114	160	272	293	405	650	785	W
η_a	54	48	38	55	49	42	56	41	45	49	41	%
PEP (load)	38	111	146	187	194	272	383	498	688	1110	1335	W
$D_{i.m.}$	30	28	33	28	29	28	36	40	28	35	30	dB

THERMISTORS

In *Outlook Vol. 5, No. 2*, an article was published describing the properties and applications of voltage-dependent resistors. Another type of non-linear resistor is the thermistor. Thermistors are thermally sensitive semiconductors and are characterised by a large negative temperature coefficient of resistance.

The variation of resistance of a thermistor may be caused by self-heating due to power dissipated in the device, by a change of ambient temperature or by a combination of these factors.

In general, the resistance of a conductor increases with an increase of temperature. There is, however, a class of materials in which the resistance decreases when the temperature increases. These materials are semiconducting oxides of iron, nickel and cobalt with small quantities of other materials added. Curves of specific resistance (the resistance of a cube of the material with sides of 1cm) plotted against temperature for various thermistor materials are shown in Fig. 1, and these clearly show the fall in resistance with an increase in temperature. In other words, these materials have a negative temperature coefficient of resistance.

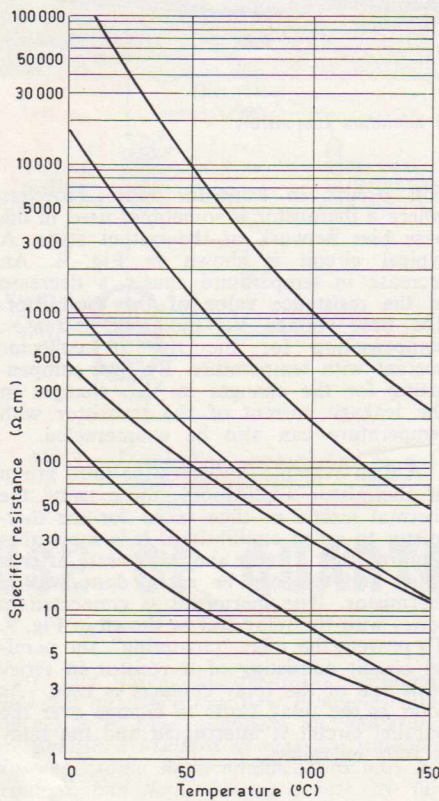


Fig. 1 — Specific resistance plotted against temperature.

If a current is passed through a thermistor, heat is dissipated within the unit and the relationship between this current and the applied voltage when thermal equilibrium has been reached is shown by the curve of Fig. 2. (Thermal equilibrium is reached when the heat lost to the surroundings just equals the heat generated in the thermistor.) The current and voltage are plotted on logarithmic scales and the voltage values are those developed across the thermistor when thermal equilibrium has been reached.

For small currents, the power consumption of the thermistor is too small to produce a noticeable rise in temperature and corresponding fall in resistance. The thermistor therefore behaves as a normal linear resistor and has a straight-line voltage/current characteristic. At point A, however, the heat produced by the current through the thermistor is sufficient to cause a fall in resistance and so the characteristic departs from the straight line. For the particular thermistor used to plot Fig. 2, point A corresponds to a dissipation in the thermistor of approximately 0.01W. At a certain

Manufacture of Thermistors

As well as the conventionally sized thermistors shown in the photograph in Fig. 4, miniature thermistors are also made and a selection of this type (magnified) is shown in Fig. 5. The normal-sized thermistors are made by extruding or pressing a mixture of the thermistor material and a plastic binding material into the shape of a rod or a disc. The rods and discs are then fired and the electrical connections fitted. Miniature thermistors are made by placing a bead of the thermistor material between

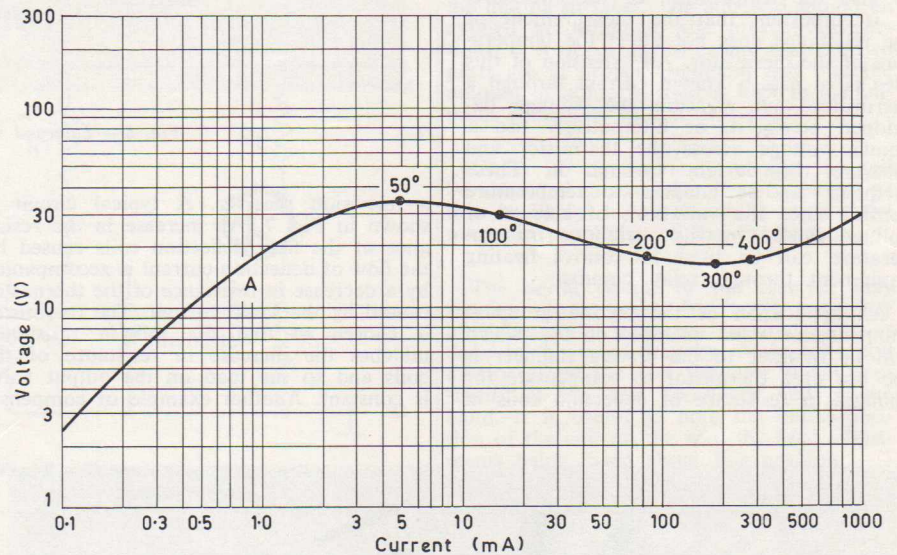


Fig. 2 — Voltage/current characteristic of thermistor.

current value, the voltage reaches a maximum value and will decrease if the current is increased further. For the thermistor of Fig. 2, this point occurs when the temperature of the thermistor is 50°C above the ambient temperature. Beyond the point corresponding to 300°C above ambient temperature, the voltage starts to rise again with an increase in current.

The resistance value of the thermistor does not change instantaneously with the change of temperature. There is a time lag between the temperature change and the thermistor reaching equilibrium. Similarly, if the thermistor has been working for some time and the current through it is switched off, there will be a time lag before the resistance of the thermistor rises to its room-temperature value. The cooling curves for two thermistors are shown in Fig. 3. From curves such as these, designers can find the time that a certain thermistor will take to react to current or temperature changes.

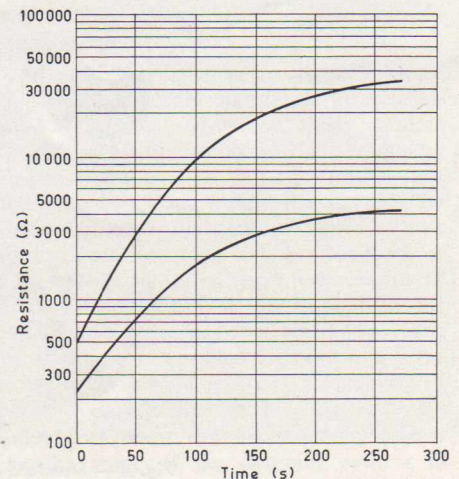


Fig. 3 — Cooling curves for two thermistors.

THERMISTORS — *continued*

two parallel platinum wires, as shown in Fig. 6. The beads are then dried and sintered. The sintering process shrinks the bead onto the wires to ensure good electrical contact. The beads are usually enamelled for protection.

Applications of Thermistors

The applications of thermistors can in general be classified into three groups. These are:

- (a) Applications which use the dependency of the resistance of the thermistor on temperature.
- (b) Applications using the negative temperature coefficient of the thermistor.
- (c) Applications using the time taken by the thermistor to reach equilibrium.

The most obvious application of the first group is the measurement of temperature. If the resistance of the thermistor at various temperatures is known, a calibration chart of resistance against temperature can be plotted. The thermistor can then be placed in an enclosure, allowed to reach equilibrium, and the resistance measured to give the temperature of the enclosure. It is important that the measurement of the resistance does not affect the temperature of the thermistor. An extension of this idea is to pass a known current through a thermistor and measure the voltage developed across it, or alternatively use a known voltage across the thermistor and measure the current through it. These methods can be adapted to temperature control since the variations of current or voltage caused by the variations in temperature can be used to control heating equipment through relay circuits.

An application of the second group is compensation. One example of this which will be familiar to the service engineer is the use of a thermistor to compensate for changes in resistance of deflection coils in

a television receiver. A typical circuit is shown in Fig. 7. An increase in the resistance of the field deflection coils caused by the flow of deflection current is accompanied by a decrease in resistance of the thermistor caused by the same current. The thermistor is chosen so that the fall in resistance matches the increase in resistance of the coils and so the load on the output valve is constant. Another example of compensa-

tion occurs in transistor radio receivers where a thermistor is sometimes used in the base bias network of the output stage. A typical circuit is shown in Fig. 8. An increase in temperature causes a decrease in the resistance value of the thermistor. The base voltage V_{be} therefore decreases, compensating for the rise in collector current with temperature. By over-compensating for the changes in V_{be} , changes in the leakage current of the transistor with temperature can also be counteracted.

A final example illustrates the third group of thermistor applications, those using the thermal inertia or time taken for the thermistor to reach equilibrium. It is sometimes required that a relay should operate after a delay and this can be easily done with a thermistor. The thermistor is connected in series with the relay coil as shown in Fig. 9. To prevent the relay "chattering", the parallel circuit consisting of a resistor in series with one of the relay contacts is used. As soon as the relay starts to change over the parallel circuit is interrupted and the relay is fully energised.

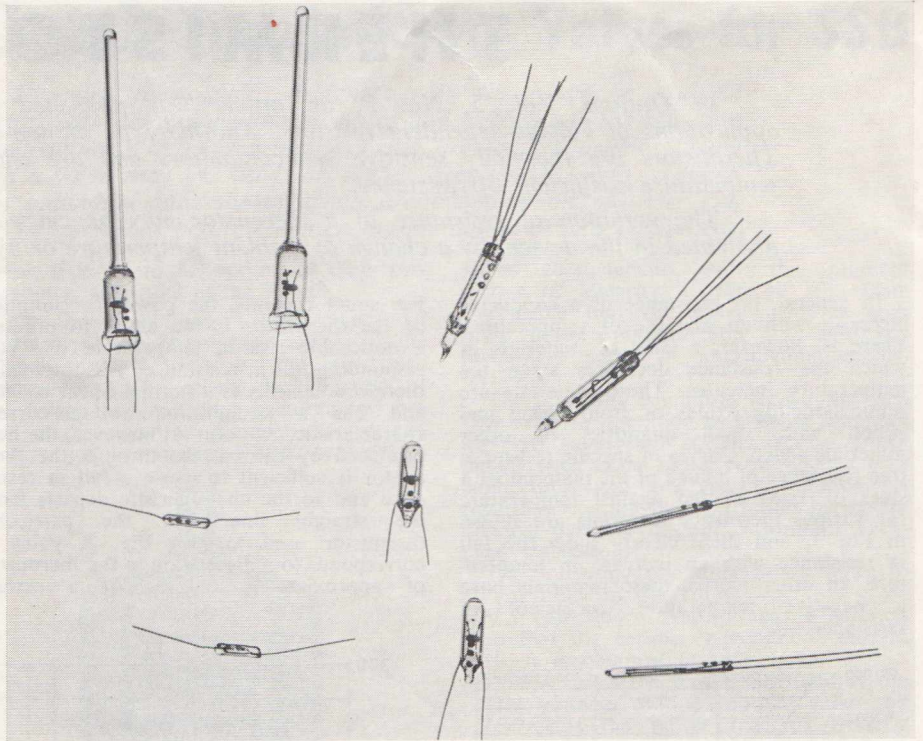


Fig. 5 — Enlarged view of miniature thermistors

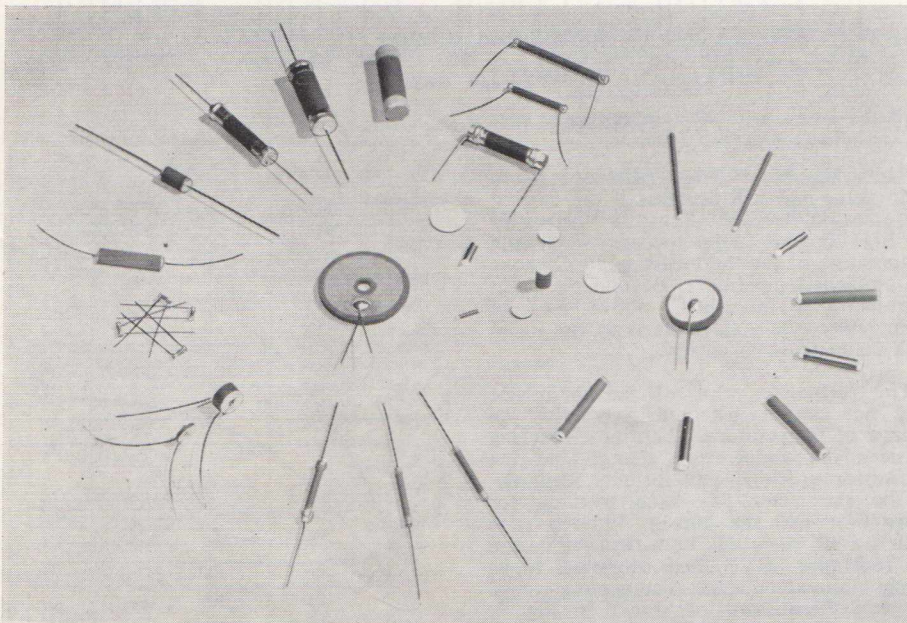


Fig. 4 — Standard-sized thermistors.

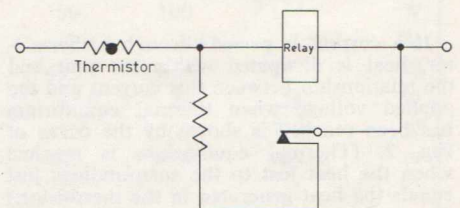


Fig. 9 — Circuit for delayed action of relay.

REPAIRING FERROXCUBE AERIAL INDUCTOR RODS

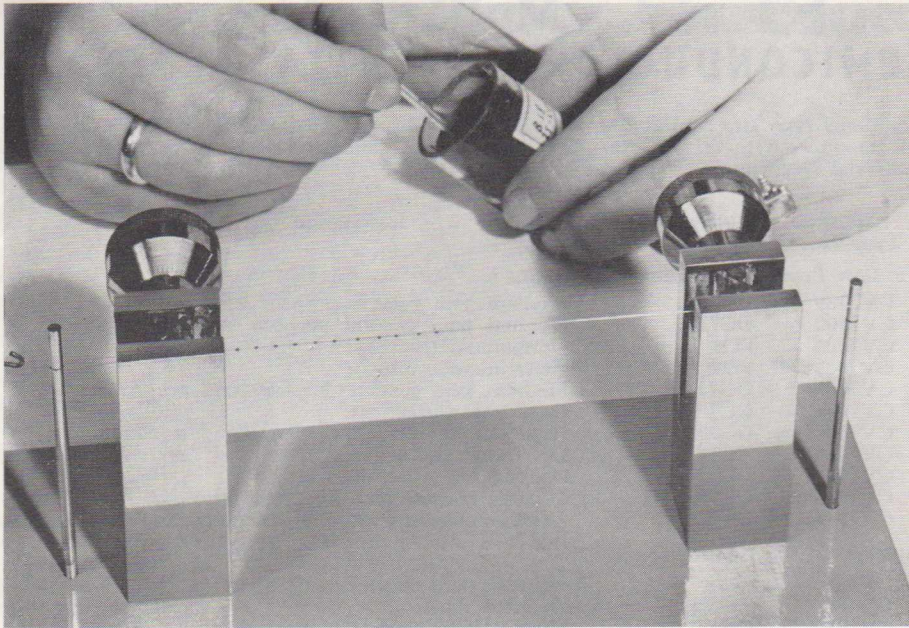


Fig. 6—Manufacture of miniature thermistors.

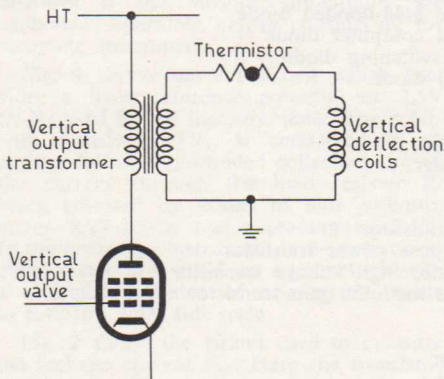


Fig. 7—Temperature compensation in a television receiver.

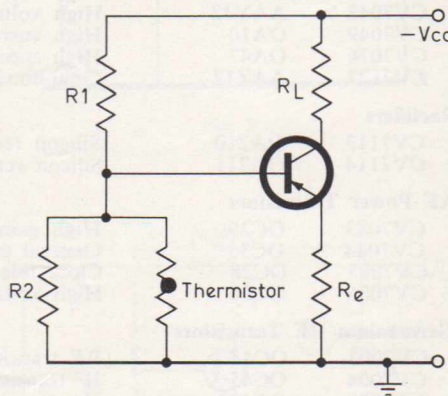


Fig. 8—Temperature compensation in a transistor radio.

Enquiries have been made recently about the possibility of using an adhesive to repair fractured Ferroxcube aerial rods. Usually the receiver can be made to operate again satisfactorily, provided the fracture is a simple one and the coils are undamaged. Most commercially available adhesives except those requiring heat treatment can be used.

The physical dimensions of a Ferroxcube aerial govern its performance in the receiver. Therefore care should be taken not to remove any portion of the Ferroxcube material by the uses of abrasives, etc., on the mating surfaces. The adhesive should be applied according to the maker's instructions. It is important to ensure that the two parts are in proper alignment and that the amount of adhesive used is kept to a minimum consistent with a firm joint.

Under no circumstances should the rod be subjected to excessive heat treatment as this is likely to permanently impair the magnetic properties of the Ferroxcube.

The aerial circuit of the receiver may require readjustment for good sensitivity after the aerial has been repaired. This is done in the usual way by moving the coil axially along the rod for best signal sensitivity at the low frequency end of the band. It is useful to note the initial position of the coil on the rod, the final adjustments being made about this position.

USE OF QUARTER-TRACK HEADS WITH MULLARD TAPE CIRCUITS

By and large, quarter-track operation does not introduce any new principles into the design of tape amplifiers, and therefore the published Mullard designs are suitable. However, some slight modifications may be required, and the following points are intended as a general guide.

At first sight, a quarter-track head would be expected to give less than half the signal output of a comparable half-track type, but improvements in head construction have, in many cases, made the difference in output considerably less. In any case, the sensitivity of the Mullard circuits is, in practice, adequate for use with most high-impedance quarter-track heads.

Recording Current

The recommended peak recording current may differ from that for the corresponding half-track head and, in general, it may be expected to be lower. If a reduction

in recording current is required, the gain of the recording output stage may be reduced by taking the output to the bias rejection network from a suitable tap in the anode load of the stage through a $0.1\mu\text{F}$ capacitor. It should be noted that the feed to the record-level indicator should still be taken from the original point at the anode of this stage, through the original $0.1\mu\text{F}$ capacitor and $470\text{k}\Omega$ resistor.

Bias Current

A similar situation to that described for the recording current also applies with respect to bias current, but the adjustment is now simply made by varying the value of the bias feed capacitor until the correct level of bias is found. As the reactance of a capacitor is proportional to $1/C$, an increase in the value of C will increase the level of bias, and a reduction in value will lower the bias.

Equalisation

In principle, equalisation is not affected by a change from half-track to quarter-track operation. However, many modern heads have an improved high-frequency response, and a change in equalisation may therefore be beneficial. As this depends on the actual head, the type and make of tape in use and, to some extent, the level of bias, individual recommendations cannot be made. Where required, adjustment of the treble-boost frequency can always be made by altering the capacitor in parallel with the treble-boost inductor—the frequency of boost is proportional to $1/\sqrt{C}$ —while the amount of boost can be varied by adjusting the value of the damping resistor in parallel with the capacitor, an increase in R increasing the boost.

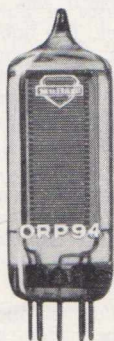


ORP94 HIGH-SENSITIVITY CADMIUM SULPHIDE CELL

The high sensitivity of the ORP94, the most recently introduced Mullard Cadmium Sulphide Photoconductive Cell, enables it to fulfil a wide variety of switching functions at extremely low light and low voltage levels, with the utmost safety of operation.

With only 10V across the cell and an illumination of 54 lux the resistance of the ORP94 falls from 800 k Ω to 200 Ω , permitting a current flow of 50mA, which is more than adequate for the operation of a relay.

The simplicity of operation of the ORP94 conveniently fits several major applicational requirements, particularly where low voltage supplies are already available. It can be used in motor cars, for daylight-controlled parking lights; and in industry for safety alarm and many other light-controlled systems. The maximum cell dissipation is 1W at an ambient temperature of 25°C. Up to 70V can be applied to the ORP94, the spectral response of which peaks at 0.67 μ m in the red region and extends to beyond 0.8 μ m in the near infra-red.



Ultra-sensitive Cadmium Sulphide Photoconductive Cell ORP94

Abridged Advance Data for ORP94

Characteristics

(at $T_{amb} = 25^\circ\text{C}$, D C conditions)
Nominal cell resistance at 54 lux 200 Ω
Equilibrium cell current at 10V D C, 54 lux, lamp colour temp. 2700°K

	Min	Nom	Max	
	25	50	100	mA
Dark current at 70V D C *			140	μ A

Absolute Maximum Ratings

V_{cell} (dc or ac pk) max 70 V

P_{cell} max

At $T_{amb} = 25^\circ\text{C}$ 1.0 W
At $T_{amb} = 70^\circ\text{C}$ 350 mW

*20 seconds after removal of illumination of 54 lux

Mullard SEMICONDUCTORS WITH CV APPROVAL

Additional types are constantly under review for inclusion in CV listings and for additional information on these and other CV types please contact the Mullard Professional and Industrial Department.

Services Type No.	Mullard Type No.	Description
AF Low Power Germanium Transistors		
CV2389	OC71	Medium gain general purpose transistor
CV2400	OC71	Medium gain general purpose low noise transistor
CV7001	PO3	Germanium transistor
CV7002	PO4	Germanium transistor
CV7005	OC71	Medium gain general purpose transistor
CV7006	OC72	Output transistor
CV7007	OC77	High voltage low power switching transistor
CV7008	AC107	Low noise transistor
CV7009	OC83/84	General purpose transistor
CV7074	OC83/84	General purpose transistor
CV7118	OC72	General purpose switching transistor
Diodes		
CV425	—	General purpose diode
CV442	OA73	Detector diode
CV448	OA81	High voltage general purpose diode
CV7040	OA202	Silicon general purpose diode
CV7041	OA95	Subminiature high voltage diode
CV7047	OA5	High voltage gold-bonded diode
CV7048	AA12	High voltage gold-bonded diode
CV7049	OA10	High current computer diode
CV7076	OA47	High speed switching diode
CV7127	AAZ17	Gold-bonded diode
Rectifiers		
CV7113	OA210	Silicon rectifier
CV7114	OA211	Silicon rectifier
AF Power Transistors		
CV7083	OC29	High gain transistor
CV7084	OC35	General purpose power transistor
CV7085	OC28	Close tolerance high voltage transistor
CV7086	OC36	High voltage medium gain transistor
Germanium RF Transistors		
CV7003	OC44	RF transistor
CV7004	OC45	IF transistor
CV7089	OC171	HF transistor
Germanium Switching Transistors		
CV7042	OC41	Low power transistor
CV7054	OC23	Core driver transistor
CV7087	OC43	Low power transistor
CV7111	OC139	n-p-n medium speed transistor
CV7112	OC140	n-p-n medium speed transistor
Silicon Transistors		
CV7043	OC200	Low gain general purpose transistor
CV7044	OC201	Medium gain general purpose transistor
CV7075	OC201	Low noise transistor
CV7117	OC203	High voltage transistor

MULLARD OMEGATRON TYPE 0.1

The omegatron is similar in principle to the magnetic resonance accelerator (now known as the cyclotron). Ions formed by electron bombardment are made to travel in a circular path through a magnetic field, at a frequency of revolution equal to their cyclonic resonant frequency. This frequency, for a constant magnetic field, is a function of the mass of the ion and number of its electron charges. If an ion of a particular type is present, it can be accelerated by the application of an RF field at right-angles to the magnetic field, the applied frequency being equal to the cyclonic frequency of the ion. The ion

will thus move in a spiral path and will eventually be collected by an electrode on the perimeter of the system. All ions of other types will continue in circular paths, and will therefore not be collected. The detection of ions of any specific mass is therefore achieved by the choice of frequency for the RF field.

Performance

The ion collector efficiency is high, and the device operates satisfactorily as a spectrometer in the pressure range 10^{-5} to 10^{-9} torr. Measurement of pressure is possible down to 10^{-12} torr.

At pressures below 10^{-7} torr the resolution is sufficiently great to provide complete separation up to mass 30. From mass 30 to mass 100 the separation is less complete but is adequate for identification of the ions present.

Operating Conditions

Magnetic field	3000 to 3500	gauss
RF field (for mass numbers 1 to 100)	50kc/s to 5Mc/s	
V_h max (adjusted for required emission)	1.5	V
I_h max	10	mA
Accelerating voltage	67	V

A Transistor Tester For Educational Purposes

This transistor tester has been designed specifically with the needs of the school laboratory in mind. Without such a device the laboratory staff may often be faced with the problem of establishing whether an experimental transistorised circuit is inoperative because of a failure in a component, faulty design or failure of the transistor itself. By the use of a transistor tester and a resistance-capacity bridge, two of these possibilities can quickly be investigated. The tester described in this leaflet is extremely simple in design and operation. It can make reasonably accurate measurements of the two leakage current I_{co} and I'_{co} and also the common emitter amplification factor α' . The common base amplification factor can be calculated from this latter parameter.

The circuit has been simplified considerably as the instrument has been designed to test low power p-n-p transistors, the transistors falling into this category being those most commonly used for educational purposes.

Principles of the Tester

It is easier to understand how the tester operates if the various sub-circuits are explained separately before considering the complete instrument.

Fig. 1 shows the sub-circuit which provides a fixed reference potential of 2.5V (X-X) used for all measurements. The reference transistor, TR₁, is connected in an emitter follower (grounded collector) circuit, the current through the load resistor R₃ being adjusted by means of bias potentiometer RV₂ for a meter reading of 2.5V. In the prototype instrument, a 0-1mA movement meter was used in conjunction with a multiplier resistor of appropriate value to measure 2.5V full scale.

Fig. 2 shows the circuit used to measure the leakage current I'_{co} . Here the transistor under test, TR₂, is connected across the reference voltage (X-X) and the collector current is measured with the base open circuit. The meter reading gives I'_{co} direct. R₅ is a limiter resistor to protect the meter movement should the transistor have an internal short circuit from collector to emitter.

The circuit for measuring the leakage current I_{co} is shown in Fig. 3, the only difference in this measurement being that the base of the transistor is now connected to the emitter.

Measurement of α' is carried out using the circuit shown in Fig. 4. The transistor

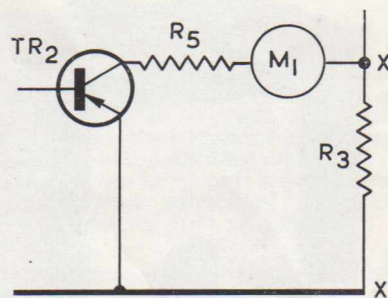


Fig. 2.

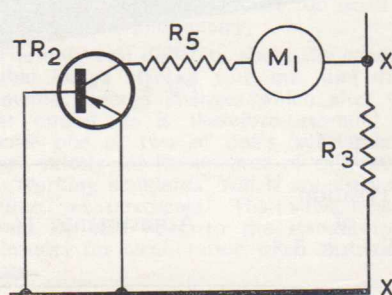


Fig. 3.

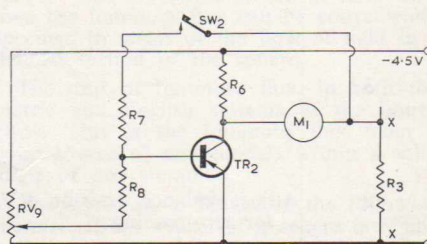


Fig. 4.

under test is now connected across the 4.5V supply and a load resistor R₆ is in series with the collector. The meter measures the signal output current from the transistor and initially will indicate a current which is reduced to zero by adjustment of the "α' adjust" resistor RV₉. If the press-button

switch SW₂ is now operated, a current of 10μA is fed into the base of the reference circuit. The meter reading then indicates the increase in collector current (I_c) resulting from a 10μA increase in base current (I_b) and hence the current amplification factor

$$\frac{I_c}{I_b} \text{ can be calculated.}$$

The grounded base amplification factor α , can also be calculated from the relation

$$\alpha = \frac{\alpha'}{1 + \alpha'}$$

The Complete Circuit

The complete circuit is shown in Fig. 5 where a three-pole four-way switch SW₃ now selects which measurement is to be taken. The diagram shows:—

- in switch position 1 the correct reference voltage is set up;
- in switch position 2 I'_{co} is measured;
- in switch position 3 I_{co} is measured and in the final position α' can be measured.

The only additional components in the unit are a low consumption pilot lamp and an on/off switch SW₁.

Practical Construction

Fig. 6 shows the prototype tester, all the components, including a meter measuring 4 x 4 in. and a large bell battery, fitting into a box measuring 12 x 6 x 3 in. deep. Three terminals marked c, b and e (emitter, collector and base) for connection of the transistor under test are also shown.

Meter Calibration

The basic 1mA movement is used in the various switch positions to measure 0-2.5V, 0-1000μA and α' readings from 0-100

$$\frac{I_c}{I_b} = \frac{1000\mu A}{10\mu A}$$

In the prototype it was found most convenient if the meter scale was therefore calibrated from 0-1 with 100 subdivisions, each one representing 10μA. Thus the meter reading is multiplied by 100 when measuring α' and read off directly for I_{co} and I'_{co} .

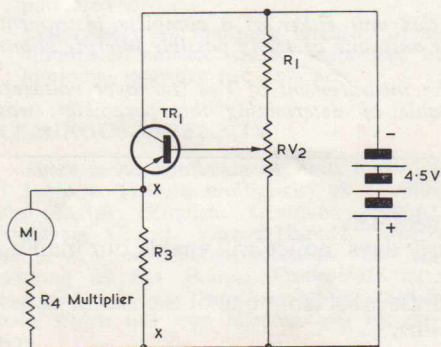


Fig. 1.

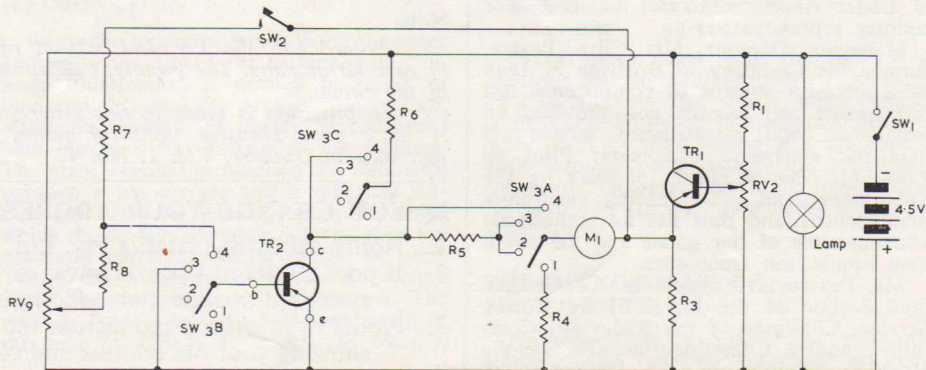


Fig. 5.



For the reference voltage the reading is multiplied by 2.5.

LIST OF COMPONENTS

- R_1 680 Ω carbon resistor
- RV_2 1k Ω linear potentiometer
- R_3 1k Ω carbon resistor
- R_4 Value must be calculated accurately for a given meter
- R_5 1.5k Ω carbon resistor
- R_6 2.2k Ω carbon resistor
- R_7 220k Ω carbon resistor, high stability 1%
- R_8 22k Ω carbon resistor, high stability 1%
- RV_9 100k Ω linear potentiometer
- SW_1 Single-pole, two-way toggle switch
- SW_2 Single-pole, push button switch
- SW_3 Three-pole, four-way rotary switch
- Pilot lamp 6.3V, 0.04A
- TR_1 Mullard OC72 transistor
- M_1 0-1mA, DC moving coil instrument.

Using the Transistor Tester

To simplify operation of the Tester, details are shown in the Table.

NORTH QUEENSLAND DISTRIBUTION



Mr. C. A. Pearce

C. A. Pearce & Co. Pty. Ltd., sole Queensland distributors for Mullard-Australia, have recently opened a branch in Townsville to cover the area between Home Hill and Cairns, including the Atherton Tableland.

The new branch is located at 13 Palmer Street, South Townsville, telephone Townsville 5864. The premises feature showroom and warehouse facilities and, no less, a Mullard Valve and Picture Tube Service Centre.

The new branch is in the capable hands of Lester Anderson, former C. A. Pearce country representative.

Managing Director Mr. Clive Pearce, formed his Company in Brisbane in 1948 as a specialist stockist of components, test instruments and records and provided an installation and maintenance service on industrial electronic equipment. Prior to 1948, Mr. Pearce spent 15 years on the Laboratory Staff of a leading electronics manufacturer and thus has an enthusiastic understanding of our goods and the attendant application techniques.

Mr. Pearce is President of the Queensland Section of the Royal Flying Doctor Service, Chairman of the Radio Sub-Committee and a Committee member of the Brisbane Division of the Institution of Radio Engineers, Australia.

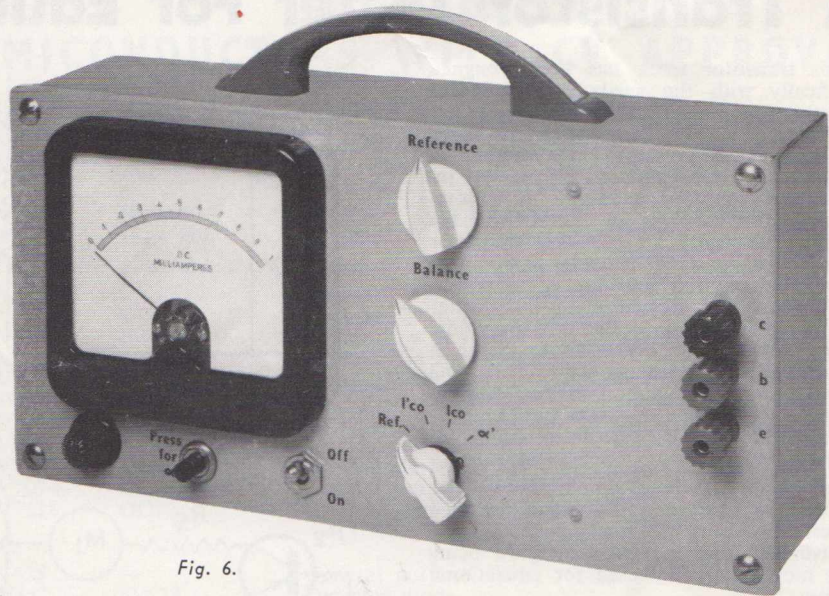


Fig. 6.

TABLE

Position of Switch 3	Adjustments	Measurement	Note
1	Adjust reference potentiometer RV_2 for a reading of 2.5V	—	—
2	—	I_{co} in μA	If the transistor is short circuit, meter reads a maximum. If transistor is open circuit, meter reads zero.
3	—	I_{eo} in μA	If transistor is short circuit, meter reads a maximum. If transistor is open circuit, meter reads zero.
4	Adjust balance resistor RV_9 for zero reading	—	If transistor is short circuit, or open circuit it is not possible to zero meter reading.
Press button	—	α'	If pointer goes off scale this indicates that the α' is greater than 100.

Accuracy:

The accuracy of the I_{co} and I_{eo} tests depends upon the accuracy of the meter. The α' measurements are within 10%.

Note:

Mullard-Australia Pty. Ltd. cannot offer this unit either as a complete instrument or as a kit of parts. The prototype illustrated is only one of many possible interpretations of the circuit.

No provision is made in this tester for the measurement of V_{To} (turnover voltage). A more comprehensive transistor tester, capable of determining this parameter, was described in Outlook, Vol. 1, No. 4.

IF YOU CHANGE YOUR ADDRESS:

1. Notify Mullard-Australia Pty. Ltd. immediately.
2. If possible, let us know in advance. Thirty days' notice will enable our mailing system to operate more efficiently.
3. Notify us in writing and include the address label from one of the recent issues showing your old address and code line.

THANK YOU.

LUMINANCE — LIGHT UNITS — ILLUMINATION

One often finds some confusion, among electronics people, about photometric units. Many engineers are familiar with a small number of units (some of them, perhaps, obsolete), but are uncertain about the rest. Discussions, therefore, tend to be at cross-purposes and to be complicated by attempts at conversion; and data sheets are readily understood by only a proportion of their users.

This state of affairs is not surprising, since the basic concepts of photometry have similar names; and a great number of units have been devised from time to time—some metric and some English—with inconvenient and unmemorable conversion factors which are often ruthlessly rounded off to 'about 10'.

There are so many units, and such a variety of usage, often extending to the employment of units taken haphazardly from metric and English systems, that any attempt to sort out the confusion must take the form of specific recommendations. This article will therefore discuss the preferred units for the main photometric quantities, and then provide conversion tables covering all the units which are likely to be still in use.

PREFERRED UNITS

In Mullard data sheets and technical publications we have employed what have seemed to be the most practical, useful, and convenient units for the devices and applications concerned. This practice, though it is defensible, has led to inconsistency and the possibility of confusion. We therefore propose to go over to the four photometric units of the metric system (candela, lumen, lux, and nit) and to discontinue the use of English units. This decision appears to be in line with the tendency of British Standard practice, since BS1991:1954 gives abbreviations for these four units and no others; and, moreover, these units have been adopted by the C.I.E.

The units relate to the four quantities which have to be defined and measured in photometry. These are, briefly:

Luminous intensity: the 'candle power' of a light source (which is assumed to be a point source, although, of course, this is not realisable in practice).

Luminous flux: the flow of light from the source, related to the solid angle over which measurement is made.

Illumination: the luminous flux falling on a surface, expressed as luminous flux per unit area.

Luminance: the luminous intensity of an illuminated surface, usually expressed as luminous intensity per unit area.

LUMINOUS INTENSITY

There is no confusion of units here. On 1 January, 1948, a multiplicity of 'candles' and lamps (English, German, Pentane, Methven, Carcel, Vernon-Harcourt, International, and Hefner-Alteneck, to say nothing of the Bougie Decimale), were superseded by the 'new candle' or **candela** (cd), which has won international recognition.

The candela is evaluated in terms of the luminous intensity of a 'black body' at the temperature of solidification of platinum. A full definition is given by Kaye and Laby (12th edition, page 71), and the practical setting-up and observation of this primary standard is fully discussed in J. W. T. Walsh's *Photometry* and in the recent Stationery Office publication *Photometric Standards and the Unit of Light* by J. S. Preston.

A number of national laboratories have evaluated the candela in this way, and they have set up secondary standards in the form of tungsten lamps, of special design, calibrated against the primary standard. There are slight experimental discrepancies between the standard candelas maintained in various countries, but these are too small to affect practical photometry.

The only real difficulty about the candela is that lamps blacken with use, and their filaments undergo changes which alter the light output. It is therefore essential to reserve one or two of one's 'substandard' lamps strictly for the purpose of calibrating the 'working standards' which are used for routine measurements. The substandards should be sent back to the standardising laboratory for recalibration when any doubt arises.

LUMINOUS FLUX

A point source of light, with a luminous intensity measured in candelas, will emit light in all directions. If one visualises a sphere with the point source at its centre, then the luminous flux can be conveniently specified in terms of the flow of light in a defined section of the sphere.

The unit of luminous flux, in both the metric and English systems, is the **lumen** (lm). This is the luminous flux from a point source of one candela within a solid angle of one steradian.

The steradian is defined in the following manner. If the radius of a sphere is r , and an area equal to r^2 is marked on the surface of the sphere, then the solid angle subtended by this area is one steradian. It is clear that the definition is independent of the actual magnitude of r . The radius may be a foot or a metre; the solid angle remains the same. It is also seen that the complete sphere comprises 4π steradians—that is, 12.57. Thus the total luminous flux from a point source of one candela is 12.57 lumens.

ILLUMINATION

When the luminous flux falls on the inner surface of the sphere, the surface is illuminated. Illumination is defined in terms of luminous flux and the area of the surface. Much photometry, of course, is concerned with luminous flux falling on flat surfaces. The error entailed in ignoring the difference between a flat surface and a spherical surface can often be ignored; but if the angle which the surface subtends is large, then the necessary correction factor should be used. Tables are available in H. A. E. Keitz's *Light Calculations and Measurements*. The error is 0.4% when the half-apex angle of the cone of light is 4° , and 2.3% when it is 10° .

The metric unit of illumination is the **lux** (lx), which is the illumination produced by one lumen falling on an area of one square metre. It follows that an illumination of 1 lux is produced on an area of 1 square metre at a distance of 1 metre from a point source of 1 candela.

An alternative (but not preferred) metric unit is the *phot*, which is one lumen per square centimetre. One phot is equivalent to 10,000 lux. It will be noticed that, as the area is smaller, the illumination produced by one lumen is greater.

Illumination can, of course, be defined in terms of any unit of area. Thus the English unit is the *foot-candle* (a term deprecated by the British Standards Institution) or lumen per square foot, which is approximately equal to 10 lux. There are also the *sea-mile candle* and the *nox*.

LUMINANCE

A surface, which is either illuminated or self-luminous, will appear to an observer to be more or less bright. Brightness, however, is a subjective concept, and the term luminance is used for the definable quantity.

Luminance is expressed in terms of luminous intensity ('candle power') per unit area. The metric unit is the **nit** (nt), which is a luminance of 1 candela per square metre. Occasionally the *stilb* (1 candela per square centimetre) is used. The *stilb* is not a preferred British Standard (it is deprecated in BS233), but it is a practical and convenient unit for some purposes.

There are two other metric units of luminance, the *apostilb* (with a submultiple, the *skot*), and the *lambert*, which are defined in terms of luminous flux per unit area. They are deprecated by the British Standards Institution. Their relationships to the preferred units are shown in the table. The *foot-lambert* (with the deprecated synonym *equivalent foot-candle*) and the *candela per square foot* are the English units of luminance.

METRIC UNITS (C.I.E.)

The preferred units, which are taken from the metric system, are, therefore, as follows:

	Unit	Abbreviation
Luminous intensity	candela	cd
Luminous flux	lumen	lm
Illumination	lux (lm/m ²)	lx
Luminance	nit (cd/m ²)	nt

These metric units, with the customary multiples and submultiples, will be generally used in Mullard data sheets and technical publications. However, in many laboratories, other units of illumination and luminance have become well established; therefore conversion tables are given for these units, the preferred (metric) unit being shown in heavy type.

THE BACKGROUND OF PHOTOMETRY

Photometry is a sufficiently, but not wholly, exact science. Its units are not

Luminance

	nit	stilb	cd/ft ²	apostilb	lambert	foot-lambert
1 nit (cd/m ²) =	1	10 ⁻⁴	9.29 x 10 ⁻²	π	π x 10 ⁻⁴	0.292
1 stilb (cd/cm ²) =	10 ⁴	1	929	π x 10 ⁴	π	2920
1 cd/ft ² =	10.76	1.076 x 10 ⁻³	1	33.8	3.38 x 10 ⁻³	π
1 apostilb (1m/m ²) =	1/π	1/(π x 10 ⁻⁴)	2.96 x 10 ⁻²	1	10 ⁻⁴	9.29 x 10 ⁻²
1 lambert (1m/cm ²) =	1/(π x 10 ⁻⁴)	1/π	296	10 ⁴	1	929
1 foot-lambert or 'equivalent foot-candle' (1m/ft ²) =	3.43	3.43 x 10 ⁻⁴	1/π	10.76	1.076 x 10 ⁻³	1

absolute, since they are necessarily expressed in terms of light—that is, the part of the electromagnetic spectrum which excites the sensation of vision. The spectral response of the eye is not equal throughout this narrow frequency band, so that photometry cannot be directly based on absolute units of energy. Further, the spectral response curve of any particular eye differs from that of other eyes and is not even constant with time or with different levels of luminous flux. Finally, the eye is subject to fatigue, after-images, and the effect of glare; and it is relatively slow to adapt to changed illumination.

The dependence of photometry on the characteristics of the eye is summed up on page 82 of Walsh's *Photometry*: 'It is more than likely that in many of the branches of practical photometry there are unrecognised sources of uncertainty which may, later on, be traced to some at present unsuspected phenomenon of vision'.

In present day photometry the tendency is to use an artificial eye consisting of a suitable photocell combined with filters which produce a spectral response curve which approximates to that of the internationally agreed 'standard observer'. The National Physical Laboratory is, however, investigating the possibility of placing the unit of light on a radiometric basis. An account of this work is given by J. S. Preston.

It should be noted that the measurement of infra-red radiation is *not* part of photometry. Data on infra-red devices are given in terms of ordinary physical units.

SUMMARY

No attempt has been made in this article to give either a rigorous or a complete account of photometric principles. It is, indeed, probably impossible to write a short and simple guide to photometry. The knowledgeable reader will, therefore, be able to point out many inadequacies and silences. These are deliberate.

Our object has been to disentangle the confusion which tends to surround the main photometric units, and to recommend the use of a coherent system. Readers who wish to go further will find the bibliography useful.

Illumination

	lux	phot	foot-candle
1 lux (1m/m ²) =	1	10 ⁻⁴	9.29 x 10 ⁻²
1 phot (1m/cm ²) =	10 ⁴	1	929
1 foot-candle (1m/ft ²) =	10.76	10.76 x 10 ⁻⁴	1

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J. W. T. Walsh. **Photometry** (3rd edition). Constable, 1958. (A standard text-book, with useful tables and a comprehensive list of definitions.)

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Kaye and Laby. **Tables of Physical and Chemical Constants** (12th edition). Longmans, Green, 1959.

(Colour temperature—not dealt with in the present article—is defined on page 73.)

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British Standard 1991: Part 1:1954. **Letter Symbols, Signs and Abbreviations: Part 1**, General. British Standards Institution, 1954, with amendments 1955, 1957, and 1960.

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J. S. Preston. **Photometric Standards and the Unit of Light** (Notes on Applied Science, No. 24). HMSO, 1961.

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Historical Notes

Hertz, 1887—found that ultra-violet light on a spark gap lowered its breakdown voltage if polished terminals were used.

Hallwachs, 1888—found that ultra-violet light dispersed a negative charge on a polished zinc plate but not a positive charge, and neutral plates became positive.

Stoletow, 1890—passed the first photoelectric current between a polished zinc plate exposed to ultra-violet light, and a grid nearby.

Elster and Geitel, 1889—found that sodium, potassium and rubidium gave the photoelectric effect with visible light.

Lenard, 1900—showed that the current was carried by electrons (discovered by J. J. Thomson in 1897) and not by metal ions from the cathode.

Einstein, 1905—proposed the photoelectric equation that the energy of a photon is $h\nu$.

Richtmyer, 1909 and—showed that the photoelectric current was linear with illumination over the range 5×10^7 to 1.

Millikan, 1916—showed the light energy absorbed equalled the energy to free the electron plus the maximum observed energy of an ejected electron.

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