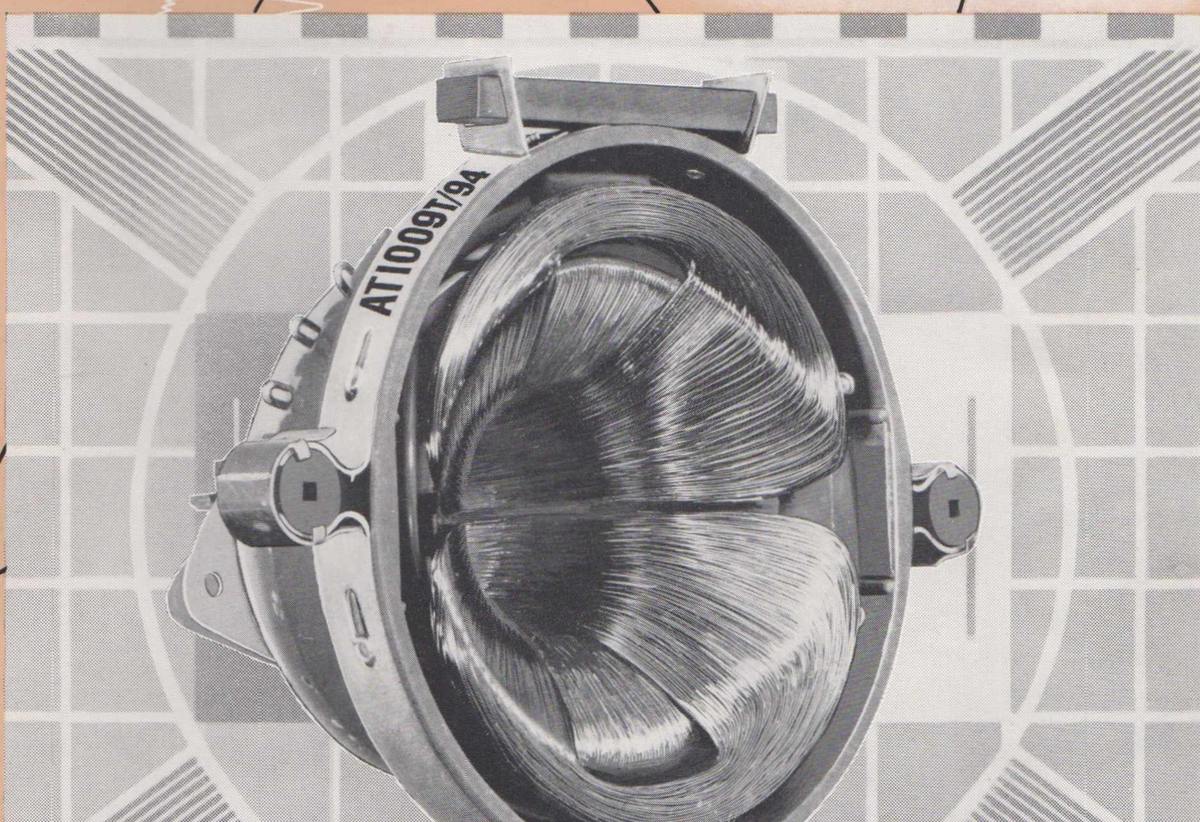
Mullard Outlook

Australian Edition



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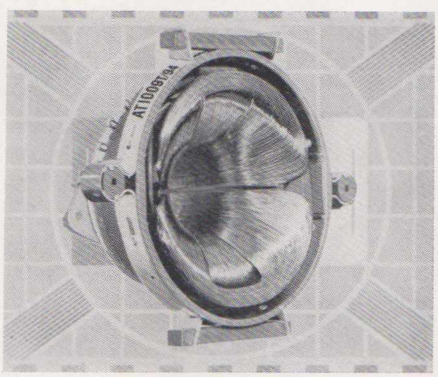

The deflection coil unit type AT1009T/94 has been specifically designed for use in conjunction with Mullard 23" picture tubes, horizontal output transformer type AT2016T/91 and linearity control type AT4008T/90. For more detailed information see page 64 of this issue.

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MULLARD LTD., LONDON.

The Festive Season and A New Year

Soon it will be Christmas, the great festival of the Christian Church and celebrated for century after century through all Christendom.

In comparatively recent times the spirit of Christmas has been vividly portrayed in the writings of Charles Dickens, perhaps too vividly — yet related to his day and the medium he used, sensible enough.

Now the medium of sound broadcasting and television brings directly into many a home that spirit at Christmas time and the thought-provoking impact of it in our daily lives throughout the year.

With each new year another challenge; may the spirit of Christmas, the goodwill and the togetherness, firmly and sincerely imbue mankind with peaceful endeavour in 1961.

VIEWPOINT WITH MULLARD

THE CORDLESS CONCEPT

An Entirely New Market Potential for A M Receivers

Cordless — a new name and an apt one for a new concept of AM radio and we have a strong feeling that the man in the street, your customer, will be using it more and more in the future as high performance, low initial cost and low running cost cordless receivers are offered you to promote and sell.

The Cordless AM receiver has come at a time when the television sales rate is dropping due to the greater number of television-fitted homes and it can be more than a consolation prize, for the potential sale of cordless receivers is every home, whether devout television viewers and already saturated with AM receivers.

NOT A GIMMICK

The cordless receiver is not a gimmick but another chapter in the evolution of AM receivers — an interesting evolution and we shall not dwell on the sets of the past, the demise of the "walnut consoles" or their companions, some rich in resonance and pregnant with microphony and some that also played records, for at some time all were a designer's proud moment: but we cannot escape the fixed pattern of twenty-eight years' acceptance of the 4/5 valve concept be it mantel set, radiogram or even portable.

Today many diverse factors, furniture fashions, a different living pattern, the advent of television and, no less, transistors, ferrite materials and new dry battery manufacturing techniques have all altered the scheme of domestic radio.

The trends have been fully covered elsewhere in market surveys, consumer group purchasing potential and so on; and it is evident that the small — perhaps not so small — home AM receiver for replacements and second and third sets, is the so-called cordless configuration.

The convenience of a sensible home receiver not anchored by a mains lead, nor a trailing aerial, nor inhibited with the fearful thought of high running cost, with performance equal to a mains-operated receiver has dictated and we believe will assure, the success of the cordless receiver.

COMPLEMENTARY TO EXISTING RECEIVER TYPES

Furthermore, we believe this type of receiver is complementary to the market group of personal portables, portables and auto receivers, particularly where the receiver is equipped with a larger and more efficient loudspeaker and blessed with a logical choice of dry battery economics. On this theme, it has been suggested that the Australian receiver manufacturers and retailers in the immediate post-war years, in their eagerness to satisfy the accumulated demand, concentrated their production and sales effort on mantel receivers and, in the process, undersold table models to their final extinction, when this type of receiver in almost every other country still enjoys a fair — in many a major — market share.

It is the opinion of some that the Australian consumer was conditioned to think in terms of low cost mantel receivers rather than table models and the industry subsequently lost the benefit of selling a higher unit turnover article. It is our thought, therefore, that it would be foolish to sell the cordless concept to fill the portable gap, for it is assumed that the psychological factors of basic laziness of human nature will not be averse to replacing the battery unit about three times during two years of regular and average use, much different to a portable used as a home receiver.

TRANSISTOR SALES FEATURE

This "send a boy on a man's errand" example can help you to effectively sell the cordless concept — the home receiver, larger, with better sound, and with heavier, greater capacity batteries, the true portable, compact, lightweight, and with small batteries for random use. The cordless receivers are, of course, transistorised—a selling feature on its own. Following issues of Outlook will show you why high performance cordless sets are equipped with Mullard transistors.

MULLARD-AUSTRALIA PERSONALITIES

With this edition of "Outlook," we are pleased to introduce our Assistant Accountant, Mr. Neil Honnor, who joined the Mullard team early in 1947.

Naturally, Mr. Honnor's forté is office management and, if at any time you should feel he could be of assistance in matters relating to accounts, please do not hesitate to call on him.

Until recent years a keen oarsman with North Shore Rowing Club and Rugby Union player for Lindfield, he has since resorted to the less strenuous sports of tennis and squash.

We look forward to the opportunity of introducing Mr. Honnor personally when next you visit our Head Office in Sydney.

DEFLECTION COMPONENTS FOR 21"/23" 110°/114° PICTURE TUBES

The Preferred Range of deflection components for 110°/114° television receivers comprises line output transformer, deflection yoke and linearity control.*

AT1009T/01 is intended for use with normal 110° picture tubes, whilst the AT1009T/94 features extra pincushion correction magnets to accommodate rectangular 23" picture tubes.

Whilst the yokes may be used with suitably designed line output transformers, the AT2016T/21 component is designed for operation with AT1009T/01 and AT1009T/94 in line output circuits employing the 6CM5/EL36 operated above the knee with stabilisation at an 18% flyback time. The high tension is provided from a 220V supply.

As the parameters of the deflection yoke influence the design of the line output transformer these specifications are tabulated:

Line Coils (parallel connected)

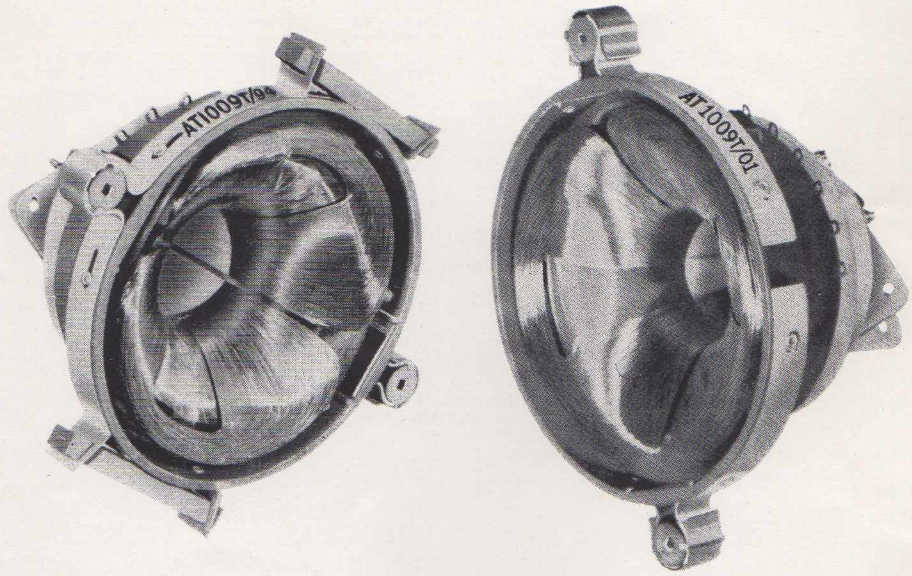
Inductance	2.9	mH
Resistance	4.7	Ω
Q at 60kc/s	55	

Frame Coils (series connected)

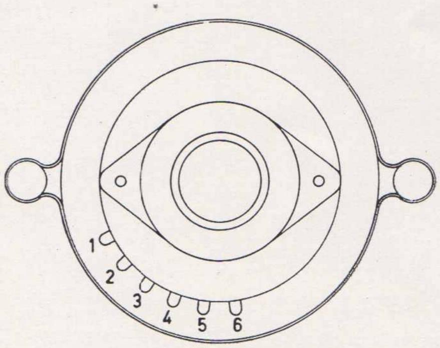
Resistance	38	Ω
Inductance	92	mH

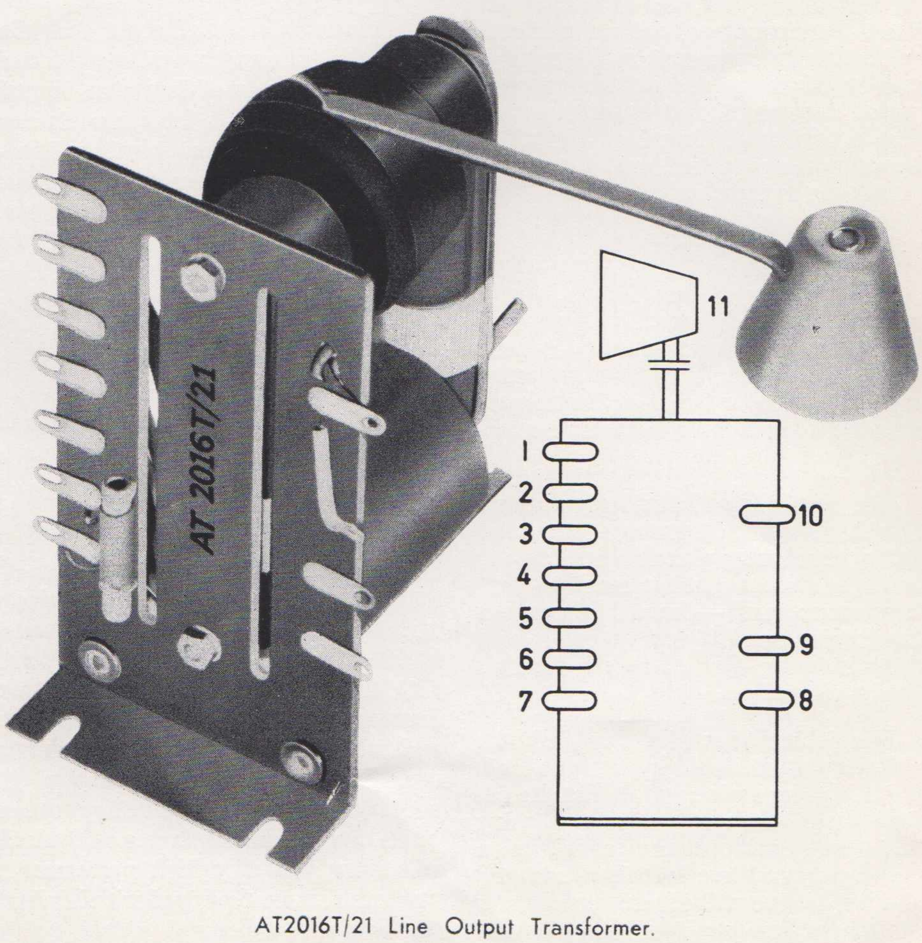
Line Coil figure of merit
($\frac{1}{2}Li^2/cm^2$)
on AW53-88
at 16 kV EHT ..... 2.7 μJ/cm²

Frame Coil figure of merit
(Ri^2/cm^2)
on AW53-88
at 16 kV EHT ..... 4.9 mW/cm²



AT1009T/94 and AT1009T/01 Deflection Yokes.





AT2016T/21 Line Output Transformer.

* *See table at the end of this article.*

NOTE: Height stabilisation is provided by an NTC resistor which has a resistance of approximately 10Ω at 25°C. For nominal vertical scan the peak to peak current requirement for the yoke is 0.425A and for horizontal scan 2.22A on an AW53-88 at 16kV EHT.

TERMINATIONS: Yoke flare down reading anti-clockwise: 1. start of line coil, 2. finish of line coil, 3. start of frame coil, 4. frame coil centre tap, 5. finish of frame coil through NTC resistor, 6. finish of frame coil.

Fig. 1 shows the circuit diagram of a horizontal oscillator and line output stage in which the AT2016T/91 and AT1009T/94 components are used in conjunction with the 6CM5/EL36 and 6AL3/EY189. In this configuration the 6CM5/EL36 is driven above the knee, and stabilisation of width, linearity and EHT is obtained by means of the voltage dependent resistor and potentiometer network in the control grid return circuit. It should be noted that an additional centre tapped winding 1, 2, 3 is provided, from which a 280 V peak pulse of either polarity is available to feed blanking circuits and gated AGC and APC systems, etc.

As with all applications where the valve is driven above the knee, this circuit is dependent upon grid wave form and it is essential that the correct driving wave shape shown be used if the results tabulated are to be accomplished. With the correct grid drive and with the stabilising potentiometer R718 adjusted for a boost additional potential of 600V, the following results will be achieved at a nominal supply potential of 220V DC.

Beam current	0	250	μA
Flyback time	18	18	%
EHT	16.0	15.0	kV
Boost Voltage	820		V

6CM5/EL36

Average anode current	105	mA
Average Grid No. 2 current	23	mA
Grid No. 2 current at end of scan	28	mA
Peak cathode current	265	mA
Peak anode current	237	mA
Anode dissipation	6.1	W
Grid No. 2 dissipation	3.5	W
EHT Regulation	4.0	MΩ

Fig. 2 shows the wave forms of the control grid driving pulse, the cathode current of the line output pentode 6CM5/EL36, the grid No. 2 current of the same valve and the anode current of the booster diode 6AL3/EY189. Adjustment of the stabilising potentiometer to ensure a boost addition of 600V should produce an end-of-scan booster diode current of approximately 10mA (at zero beam current) and minimum cathode current in the 6CM5/EL36.

It should be noted that the total capacity of the loading on the winding 1, 2, 3 should not exceed 100pF nor should the yoke winding 4, 6 be loaded with more than 80pF otherwise the third harmonic tuning will be affected. The capacitor C718 which controls the ratio of EHT to boost addition is supplied already terminated on the transformer assembly. The peak value of flyback pulse appearing at the deflection yoke winding relative to ground is approximately 450V and insulation of the coupling capacitor C719 and linearity control AT4008T/90 should be arranged with an adequate safety factor.

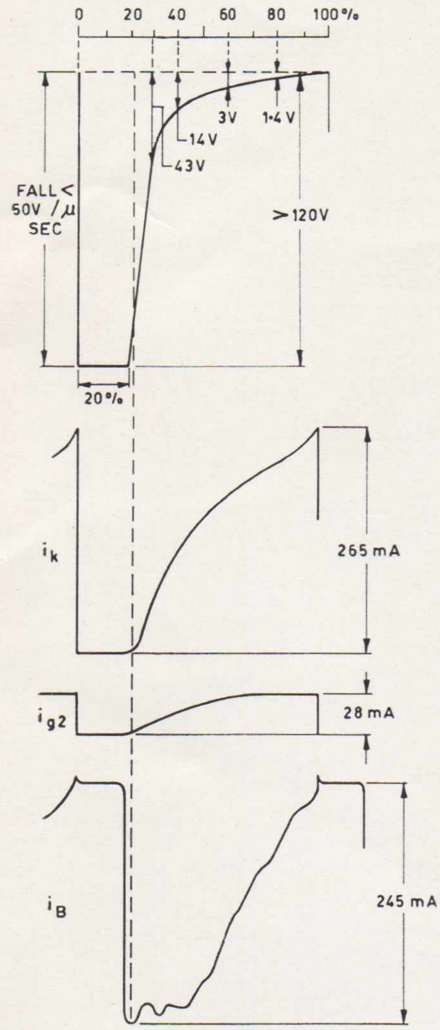


Fig. 2

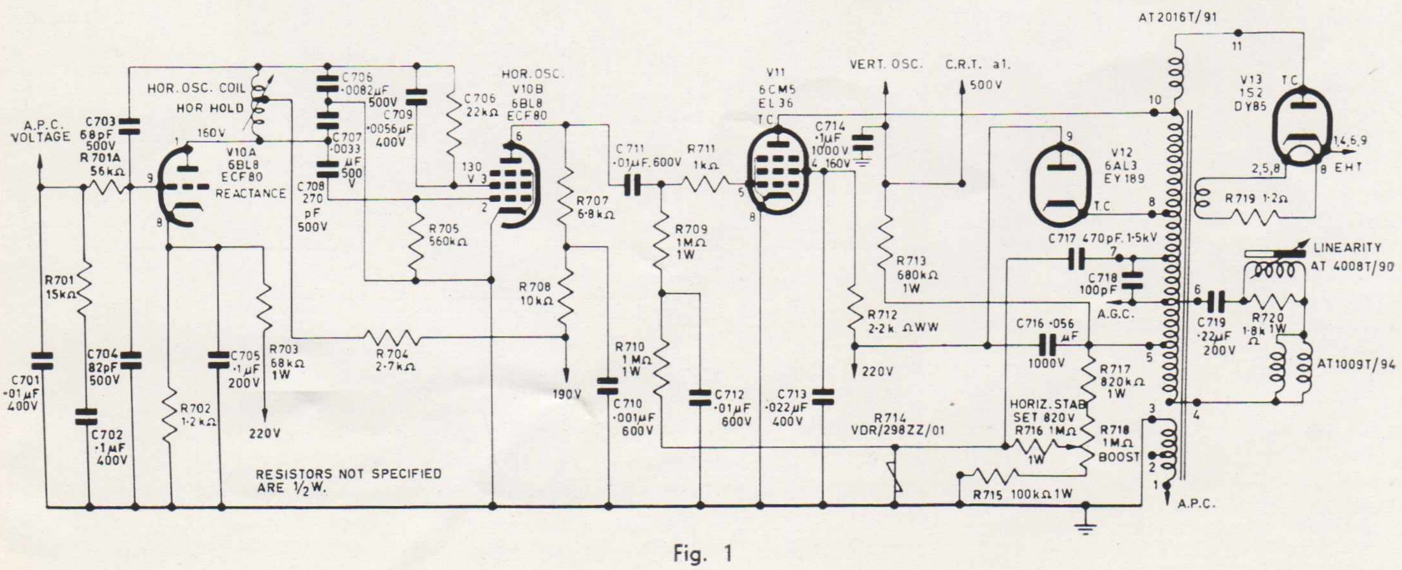


Fig. 1

Measurements have also been carried out on these components with the 6CM5/EL36 driven above the knee without stabilisation, the modifications to the schematic of Fig. 1 being the return of the 6CM5/EL36 grid leak to ground, the removal of the voltage dependent resistor and its coupling capacitor C717 and the stabilisation potentiometer network chain R716, R717, R718 and R715. To obtain the same ratio of EHT to boost addition an anode to cathode supply voltage for the 6CM5/EL36 of some 190V is required. For reasons of compromise, not to mention some degree of protection for this valve in the event of loss of drive, a nominal 215V rail was chosen and a 100Ω unbypassed cathode resistor fitted to this stage.

Measured results are tabulated hereunder:—

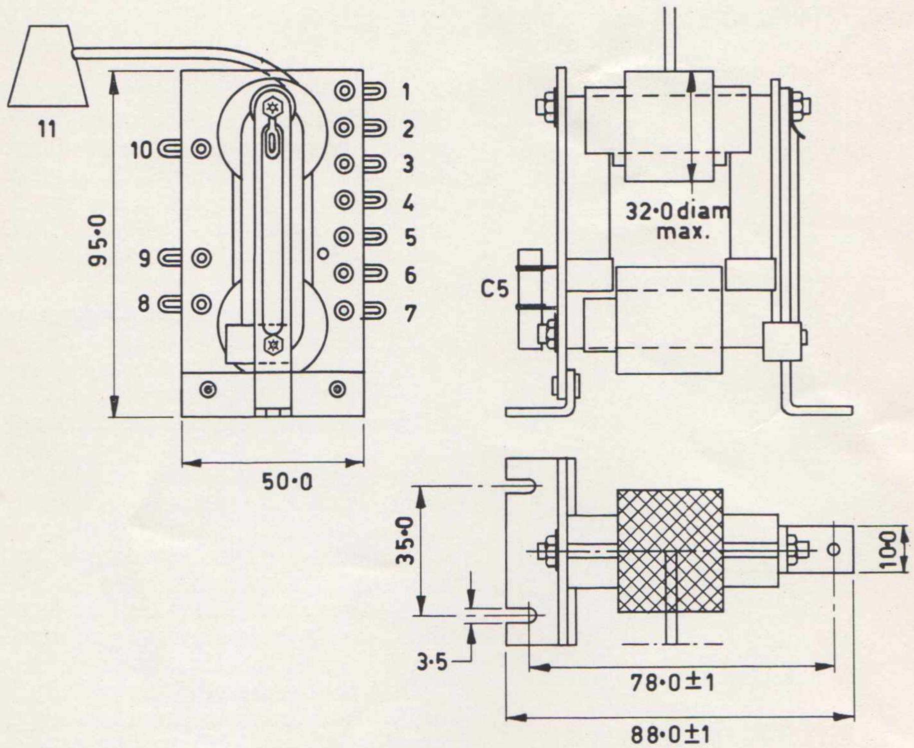
6CM5/EL36:

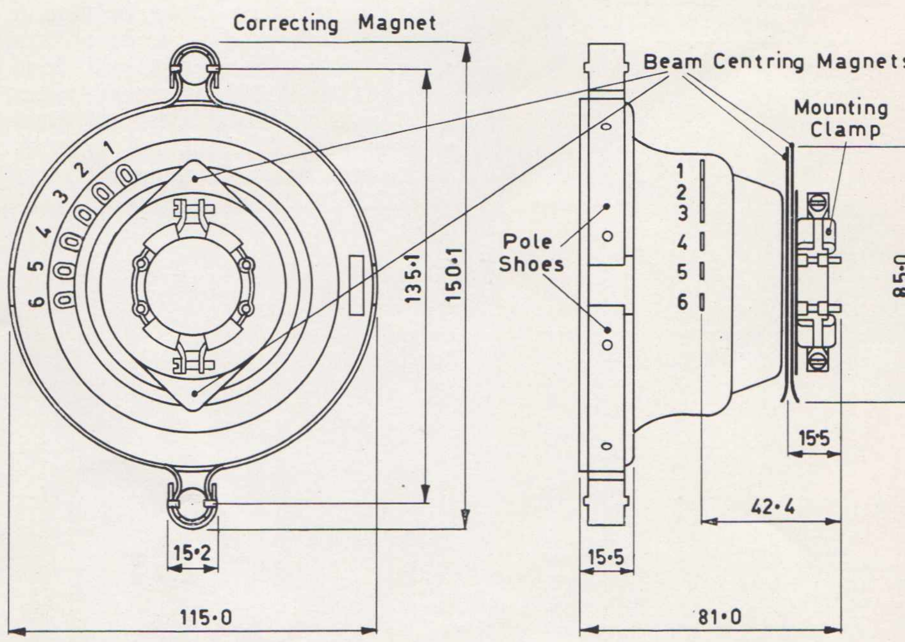
	Ib = 0μA	Ib=200μA	
Mean Cathode Current	137	142	mA
Peak Cathode Current	245	246	mA
Mean Screen Current	25	24	mA
Peak Screen Current	62	62	mA
EOS Screen Current	14.5	14.5	mA
Mean Anode Current	112	118	mA
Peak Anode Current	225	225	mA

6AL3/EY189:

Mean Diode Current	112	118	mA
Peak Diode Current	244	257	mA
EOS Diode Current	Negligible	12	mA
EHT	15.4	14.1	kV
Boosted High Tension	800	700	V
HT Rail Potential	212	209	V
EHT Regulation		6.5	MΩ

The drive circuit used for these measurements is shown in Fig. 1.





110°/114° DEFLECTION COMPONENTS

AT1009T/01 . . . 21″ version standard yoke with NTC resistor less leads.
AT1009T/90 . . . 21″ version without NTC resistor, but with lead and plug.
AT1009T/93 . . . 23″ version without NTC resistor, but with lead and plug.
AT1009T/94 . . . 23″ version with NTC resistor, without lead and plug.
AT1009T/95 . . . As for type /01, but with lead and plug attached.
AT2016T/21 . . . Line Output Transformer with capacitor.
AT2016T/91 . . . Line Output Transformer with capacitor and anti-ringing circuit.
AT4008T/90 . . . Linearity control.

HEAT FROM MICROWAVES

Magnetrons are usually thought of in connection with radar transmitters; and, of course, most of the development work on the magnetron has been in that field — which still remains the chief application of the device. But, as so often happens, a device which has been developed for one purpose is found (perhaps after some modification) to be useful for other purposes. This is happening with the magnetron.

Experimental microwave oven

One new and unfamiliar use for the magnetron is the generation of high-frequency power for dielectric heating of industrial products, for the treatment and cooking of food, and for medical diathermy. The reasons why the magnetron is being used in this way will appear from a consideration of the principles of dielectric heating.

R.F. HEATING

There are many methods of heating by electrical means. Apart from the more obvious ones, there are two methods which use high-frequency power. The first is induction or 'eddy current' heating. In this method, RF power is fed into a coil — which in practice is likely to be a few turns of water-cooled copper tubing. The material which is to be heated is placed in or alongside the coil, and circulating currents are therefore induced in the material. With an adequate RF source and a suitably designed coil, the temperature of the material can be raised to any desired level very quickly, since the heat is generated within the material and does not have to penetrate from the surface inward. The method is versatile and easily controllable within any required limits, and it is widely used in many industries, including valve manufacture. However, it is limited to the heating of conductive substances.

DIELECTRIC PRINCIPLE

If a non-metallic material is to be heated — for example, plastics, wood, glue, rubber, food, or even the human body — a different principle is necessary. The currents which can be induced in such materials are negligible, and no useful heat is generated.

The alternative principle is dielectric heating. It depends, not on the setting up of eddy currents, but on the forced vibration of the molecules within the material. Like the induction method, it has the outstanding advantages of speed, uniformity of heating, and controllability.

The simplest dielectric heating unit consists of two metal plates connected to an r.f. generator. The molecules of any substance placed between the plates will tend to align themselves with the electric field; and, as the field reverses direction, so will the molecules. If the field alternates at a high frequency, heat will be generated by what may be called 'intermolecular' friction.* The process resembles the unwanted heating-up of components by dielectric power loss in r.f. communications equipment. The difference, however, is that in the heating unit the greater the power loss the better. Ideally, all the r.f. energy will be converted into heat, and none will be 'transmitted.'

MORE HEAT

The heating effect in a particular substance depends on the dielectric constant and loss factor of the substance. Clearly, if say rubber is to be heated, then the values of these two factors for rubber have to be accepted; they cannot be changed in any way to give a better heating effect. However, two other factors are controllable: the strength of the electric field, and its frequency, which, broadly speaking, determine the speed and frequency of molecular movement.

If the voltage between the two plates is increased, then the increase of the heating effect is proportional to the square of the voltage. Unfortunately, this way of getting more heat is limited by the need for good insulation. If the workpiece is thin, it may easily be punctured by voltage breakdown between the plates. And, in drying processes, the presence of moisture provides its own disadvantages.

A more practicable course is to increase the frequency. Thus, if the frequency is increased from 30Mc/s to 3000Mc/s, then the power loss is increased 100 times. In fact the advantage gained may be even greater, because the lossiness of many materials tends to increase at higher frequencies.

Not unnaturally, this way of improving the heating effect has its own limitations. At high frequencies the available power is being absorbed by the material at a very high rate, and the depth to which the r.f. field can effectively penetrate the workpiece is reduced. However, the limitation is not too severe, and microwave dielectric heating compares favourably with other methods in this respect. For example, with infra-red radiation, effective heating may be limited to within a millimetre of the surface. In both infra-red and microwave methods, the process time may have to be increased to ensure through-heating, but in microwave units the power density can still be relatively large and the heating time relatively short, and workpieces several centimetres thick can be effectively treated.

R.F. GENERATOR

The maximum useful frequency is, in fact, well up in the region of thousands of megacycles per second — or gigacycles per second (Gc/s), to use a unit which eliminates a few noughts.

Until recently, RF dielectric heating units were fed by conventional valve oscillators. These sets used, in the earlier days, ordinary transmitting valves. As dielectric heating grew, it became worthwhile to develop special oscillator triodes for the purpose, and many types gave (and still give) excellent service at the more conventional industrial frequencies of say 30 to 50Mc/s. Among these types are

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** The actual mechanism is fully discussed by L. Hartshorn in the January, 1945, issue of Wireless World.*

the Mullard TY5-500, TY6-800, TY8-15A, TY12-20A, TY12-25A, and TY12-50A, which provide output powers ranging from 1kW to 80kW.

Operation of dielectric heating units at 30 to 50Mc/s can produce interference with broadcast reception. Because of this, as well as to obtain the benefit of increased heating effect, it is desirable to shift to much higher frequencies. However, the efficiency of an RF triode falls from about 75% at 30Mc/s to say 20% at 1000Mc/s (1Gc/s). At this latter frequency the power available economically may be as little as 1kW. It is for this reason that the c.w. magnetron has been introduced as an r.f. generator for dielectric heating. It can provide high powers at 1Gc/s with an efficiency of 70%.

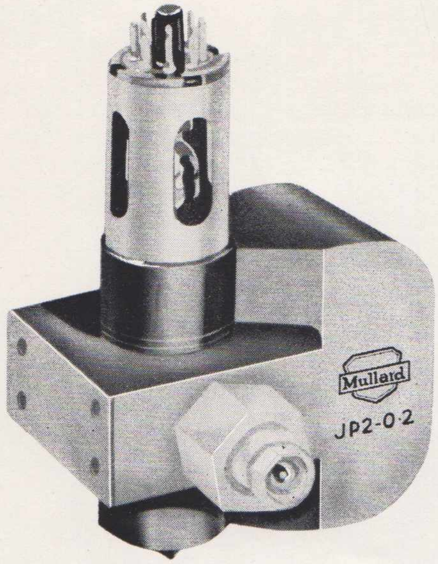
The design of a magnetron for this purpose is complicated by certain dimensional considerations. In practice, for applications where an output of up to 5kW is required, an efficiency of 60% is achieved in the 2.45Gc/s industrial band; while for higher power levels the 0.915Gc/s band is more suitable. At frequencies above 2.45Gc/s the depth limitation would become significant, and usefulness would be restricted to work in which deep penetration was not required.

AVAILABLE MAGNETRONS

Microwave heating is in a state of development, with present emphasis on the 2.45Gc/s band and on output powers of about 5kW. Under these conditions a heating effect sufficient to disintegrate any material with a trapped water content can be developed by existing magnetrons such as the Mullard JN2-2.5A and JN2-2.5W. It is clear that an adequate power density, with something to spare, can be achieved at 2.45Gc/s! Where only low power is required, the Mullard JP2-0.2 provides up to 200W. Magnetrons for dielectric heating at higher powers than 5kW are being developed.

CIRCUITS

The use of parallel metal plates becomes rather difficult at high frequencies, because the dimensions of the unit are comparable with the wave length (2.45Gc/s corresponds to approximately 12.1cm). In practice, either small aerial systems (applicators) with good focusing properties, or cavities with dimensions of a few wavelengths, are used. The RF energy is fed to the unit by waveguides.



JP2-0-2

Applicators, such as the four shown, are not very efficient for normal purposes, and there is also a good deal of stray radiation which could be harmful. But in strictly controlled low-power applications such as medical diathermy, they are useful. Applicator 'A' is a parabolic reflector with a helical monopole which gives circular polarisation of the electric field, and good focusing. It is used for heating the external fatty layers of the body. 'B' gives axial polarisation and penetration to deeper tissues. 'C,' a trough of parabolic section with two helixes excited in phase, and elliptical polarisation, allows depth treatment over large areas. 'D' is a slot radiator with linear polarisation, and it provides treatment over a selected small area.

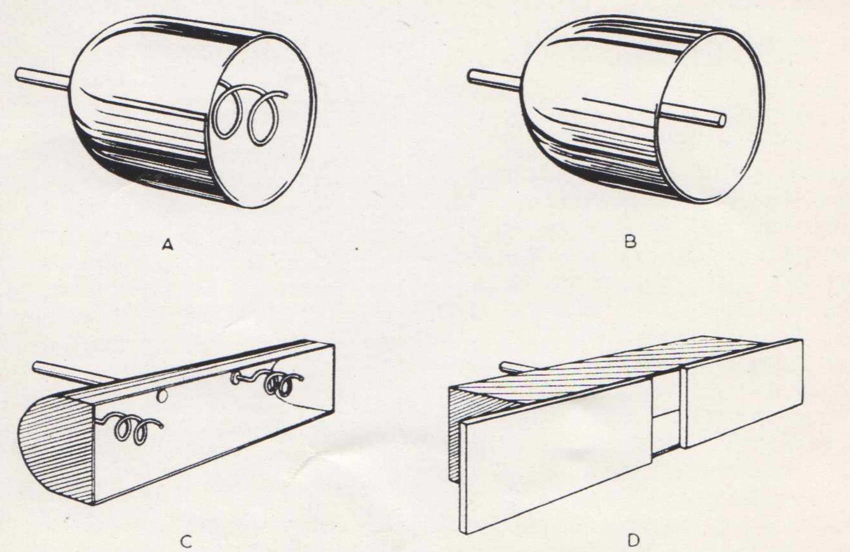
Cavities are the normal form of heater for industrial applications and food processing. The illustration at the beginning of this article shows an experimental oven which has been built in the Mullard laboratories for demonstration purposes. (Note: Mullard Ltd. do not manufacture or supply microwave ovens.) In a cavity, multiple reflection provides all-round radiation of the workpiece, and heat is developed efficiently and effectively. Standing wave patterns, which could give rise to non-uniformity and local overheating, are broken up by a rotating reflector or 'stirrer.'

Ovens can be built with conveyor feeds for the processing of workpieces on a production line. The input and output ports must be long, and the conveyor should also be continuously loaded with workpieces or lossy dummies to attentuate any stray radiation.

Fluids and pastes can be treated as they pass along a low-loss pipe mounted axially in a cylindrical waveguide in which a radial electric field is set up.

APPLICATIONS

Diathermy has already been mentioned. Industrial applications include drying, depth treatment of plastics and other materials, the bending and gluing of plywood and veneers, preheating of various non-metallic substances, and so on.



Diathermy applicators

JN2-2.5A

Special applications in the food industry include sterilisation and dehydration. These processes can be performed with a high degree of precision and repeatability, and the manufacturer can put on the market a product which has uniform keeping qualities, texture, appearance, and flavour, from batch to batch — a uniformity which is usually demanded by the customer.

Microwave cookery includes the thawing of frozen foods, and the final preparation of pre-cooked meals. It will probably be a long time before there is a magnetron in every home, though this would introduce a note of variety into the life of the service engineer. However, in canteens and restaurants there are definite and substantial advantages in microwave cookery, and a number of installations have already proved their worth. The greatest advantage is that thawing and cooking can be performed very rapidly, since, as in the industrial applications already discussed, the heat is generated inside the substance which is to be heated. Thus, where there are large and sudden variations in the demand for particular dishes, these can be met with comparative ease, and the customer need not be kept waiting or told that a dish is 'off the menu.'

The flavour of food cooked by microwaves can be better than usual, since water is dispensed with; and there is evidence that the retention of vitamins and so on is not lessened and may be increased, since the cooking time is short and, once again, no water is used.

One disadvantage is that, as foods are cooked from the inside, the surface may be unconventional and perhaps unacceptable (crustless loaves, for example); but this can be easily remedied by a short period of normal external heating.

DECOUPLING CAPACITORS IN GROUNDED-EMITTER AMPLIFIER AND OSCILLATOR STAGES

The decoupling capacitors in a conventional transistor circuit are connected to the emitter side of the supply. Distinct advantages result from decoupling to the collector supply line. Alternatively, with the emitter decoupled to the collector supply line, the base potential divider may be decoupled to the emitter.

CONVENTIONAL CIRCUIT

It is common practice to arrange the decoupling capacitors in a grounded-emitter amplifier or oscillator stage as shown in Fig. 1.

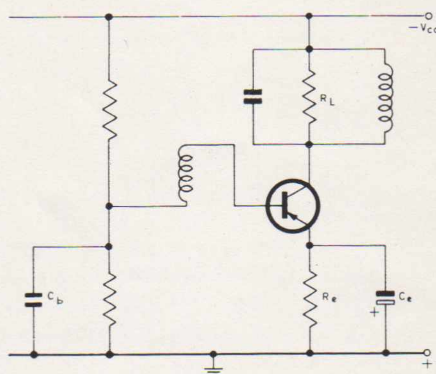


Fig. 1 — Conventional decoupling for grounded-emitter amplifier or oscillator stage.

In this circuit, the return path of the amplified collector current to the emitter, in the absence of a further decoupling capacitor, is through the DC supply. For correct functioning of the stage, especially when a number of stages are connected in cascade, the supply must be of low impedance. Consequently the circuit may be sensitive to the increase in the internal impedance of the battery towards the end of life.

ALTERNATIVE CIRCUIT

Fig. 2 shows an alternative method of decoupling the stage, which has a number of distinct advantages:

(*a*) a high-impedance supply is of little consequence;

(*b*) additional decoupling of the supply may not be necessary; interaction between stages is reduced as each stage is individually decoupled;

(*c*) R_e acts as a decoupling resistor to signals on the emitter line.

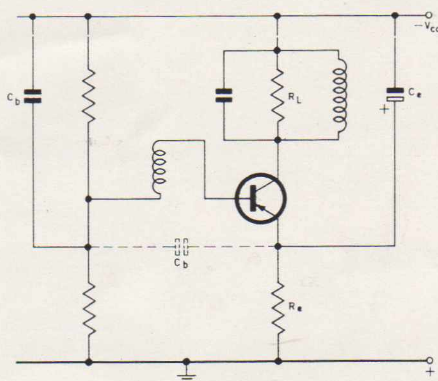


Fig. 2 — Alternative method for decoupling grounded-emitter amplifier or oscillator stages.

On account of (*c*) and the advantage of having one side of the decoupling capacitors connected to ground, it will often be preferable to ground the collector supply line.

As in Fig. 1, the return path of the base signal is through the emitter decoupling capacitor. The circuit can be further modified so that the decoupling capacitor for the base bias chain is as shown by the dotted line. C_e is then effectively removed from the input circuit, and its capacity can be appreciably smaller than in Fig. 1 without upsetting the circuit operation. (The reactance of C_e now appears in series with the load.)

CONCLUSION

In view of the above advantages, it is suggested that the circuit of Fig. 2, with either of the base decoupling arrangements, should be adopted in the absence of special circumstances which justify that of Fig. 1.

This article is based on a memorandum circulated by K. Holford of the Mullard Research Laboratories.

Mullard

STEPPING TUBES

COUNTING

The main purpose of stepping tubes such as the types described is to indicate the number of pulses occurring at certain points in electronic circuits. These pulses may be derived from many sources: signals from a photocell counting articles on a conveyor belt, random signals from some nucleonic process, or regular pulses such as from AC mains. They may be widely spaced (one or two a day) or so closely spaced that the glow in the 'units,' 'tens,' and 'hundreds' tubes will be circulating so fast that it will appear as a continuous ring.

Besides simple counting, there are two more complex applications — both of which, however, have *counting* as a basis.

TIMING AND BATCHING

If the input signals being counted are the cycles of the 50 c/s mains, then, when the counters read 5-0-0, ten seconds will have passed. With suitable circuits, the tubes can in fact be made to indicate the time of day. A more important use of timing is in the control of processes such as heating or welding. If the circuit can be arranged to take some *action* after a particular number of input signals, then all sorts of control systems can be devised. Thus an RF heating process can be switched off (or to some other temperature) after exactly so many cycles of the mains (representing, say, five seconds). It is even possible to control action which lasts as little as one or two mains cycles. Thus a spot-welder can be controlled to give, say, two cycles of weld, three cycles of rest, and another two cycles of weld.

If the input signals are provided by the passage of articles in front of a photocell, then some action can be initiated when a certain number of articles have passed. Thus a stream of articles from a production unit can be chopped into batches containing any required number. It does not matter if the articles are spaced unevenly on the conveyor belt, so long as there is a gap between each.

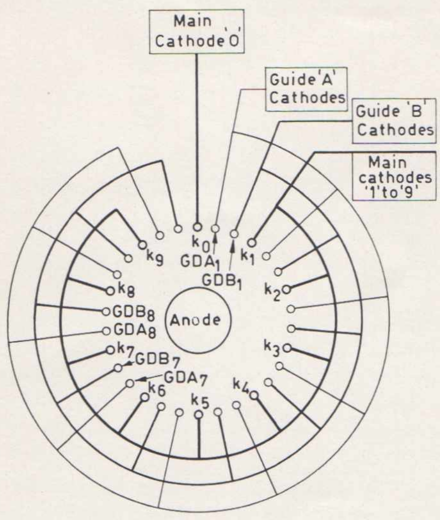
SELECTOR TUBE

How is the glow driven round the stepping tube by the input signals? And how, at any particular point, does the tube initiate external action? The best way to answer these questions is to consider the construction and operation of one type of stepping tube which is know as a *Selector*.

The purpose of a tube such as the Mullard Z502S is to 'select' a particular input signal (say the 3rd, or the 29th) and to provide some external action as soon as that signal has been counted.

DRIVE

The tube contains a circular anode surrounded by a ring of 30 identical rods, which are 'cold' cathodes. The



Counter tube electrodes

bulb contains a mixture of inert gases. If a DC voltage, greater than a certain value, is applied with positive to the anode, current will flow, and a glow will appear on the cathode. The problem now is to move this round the circle of cathodes in ten distinct steps. Every third rod is a 'main' cathode, and those in between are 'guides,' first a guide 'A' and then a guide 'B'. The cathodes (going clockwise) are GDA_1, GDB_1, k_1, GDA_2, GDB_2, k_2, and so on to GDB_9, k_9, GDA_0, GDB_0 and k_0. (The diagram, for the sake of simplicity, represents a *Counter* with k_1 to k_9 taken to a common connection.)

If any cathode is more negative than any other cathode (that is, if its potential difference from the anode is the greatest in the tube) *this* cathode will be chosen by the glow. If, therefore, the glow is at k_7, the obvious way of shifting it to the next cathode (GDA_8) is to make GDA_8 more negative than k_7. Similar means can then shift the glow to GDB_8.

In practice, two successive negative pulses are applied, the first to the 'A' guide and the second to the 'B' guide.

These pulses are derived from the input signal. Transfer from the 'B' guide to the main cathode takes place at the end of the second negative pulse, since the guides, when unpulsed, are made to sit at a positive voltage with respect to the main cathodes and the glow will then obviously prefer k_8 to GDB_8.

It may seem that, as k_1 to k_9 are all at the same potential, the glow might jump from GDB_8 to, say, k_4 or k_9 instead of to k_8. However, k_8 has an advantage: it is already in the ionised region which is set up by the glow on GDB_8 (it is 'primed'), and for this reason the 'negativeness' which it requires to attract the glow is less than for any other main cathode.

OUTPUT

When the glow has been driven to k_0 (or, in the selector tube, to any chosen cathode) an output signal must be obtained. This is arranged by connecting a resistor in series with the output cathode. When the glow reaches this cathode (which has a fixed negative bias) the consequent flow of current generates a voltage pulse across the resistor; and this pulse can be used either to operate the next counter tube or a relay or some other device. The output signal must normally be amplified and shaped before it is suitable for these purposes.

COUNTER TUBE

If a stepping tube is required only for counting, it will have to provide an output signal only once for every revolution of the glow. When the 'units' tube has reached ten it must pass on a signal to the 'tens' tube — which will then indicate '1', while the units tube will go on to count '1, 2, 3, . . .' all over again.

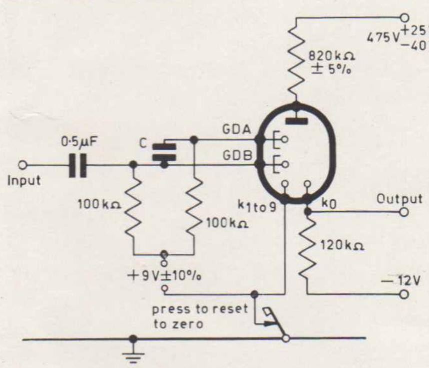
No action is required from any tube anywhere but at its tenth position. Thus the main cathodes '1' to '9' can all be brought out to a single pin. The tenth cathode must still have its own connection. The *internal* structure is the same as that of the *Selector*. The Mullard Z303C is a counter tube of this kind.

INDICATOR TUBE

The indicator tube, such as the Mullard Z503M, is a simpler device. It has only to show what is happening in a counter circuit which otherwise would not have a visual indication. The tube contains an anode and ten cathodes. Each cathode is taken to the appropriate point in the counter, and a glow appears when that particular point is reached by the counting process. The indicator tube can be thought of as ten separate 'neons' in one bulb. The information is visually presented in just the same way as by the counter tubes which may be in the same installation.

DRIVE CIRCUITS

Both the Z303C counter and the Z502S selector need a drive circuit which, from the incoming signal, will produce two successive negative pulses for the guides. Two possible drive circuits are shown.



Sine wave drive

SINE WAVE DRIVE

In this circuit the 'negative pulses' are the negative half-cycle of the mains and a delayed version of it, the delay being produced by a suitable network. This kind of drive is limited to certain applications. If it is used for counter chains, there is a frequency limit below which operation may be unsatisfactory; for, since each stage in a decade chain divides the frequency by ten, the steepness of the leading edge of the input signal is decreased and becomes unsatisfactory for use as a triggering pulse.

INTEGRATOR PULSE DRIVE

The double triode V1a/b, with the diode V2a, amplifies and shapes the input pulse. Its output is fed via C4 to the integrator network R12 C5, which delays the pulse for the 'B' guides. Diode V2b prevents overswing of the guide voltages when the circuit is returning to its standby condition.

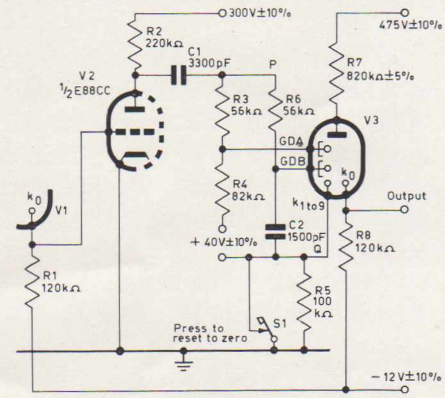
DIRECTION OF ROTATION

There is no reason at all why stepping tubes should not be driven counter-clockwise if this is desired. Guide 'B' is then pulsed negative prior to guide 'A'.

COUPLING CIRCUITS FOR COUNTERS

When it is desired to count to more than ten, it is necessary to use a chain of counter tubes. The output pulse from a Z303C counter tube is the wrong polarity and, besides, its amplitude is too small to drive the next tube. It is therefore necessary to amplify and invert the pulse before it is applied to the integrator network of the next counter.

A suitable circuit is shown. V1 is one counter tube. When the glow in this tube arrives at k_0, a pulse is generated across R1. This pulse is amplified and inverted by V2, and is then fed via C1 to the integrator network R3 R4 R6 C2 and thus to the next counter tube V3. This integrator network must operate under different conditions from those discussed earlier. Whereas the drive circuit for the first counter receives input signals of definite length, the input circuit to the second counter has to accept the output signal as supplied by the first counter. If the glow in V1 is stationary at k_0, V2 will be switched into continuous conduction. The integrator network is designed to facilitate this condition.



Coupling circuit

RESETTING

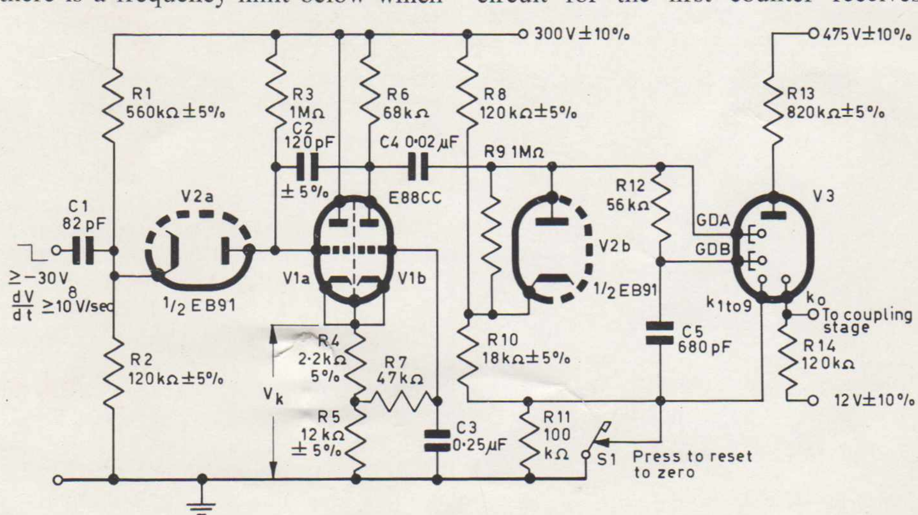
When starting a count, or any other stepping tube operation, it is obviously desirable to reset the glow in the tubes to zero. This can be done either by the push-button S1 shown in the drive and coupling circuits, or by a pulse. In both methods the zero cathode k_0 is taken more negative than any other electrode, and it is held negative until the glow steps to this position. The negative voltage must be greater than used in normal transfer, since k_0 will not necessarily be primed (the glow might be at k_5 on the other side of the tube). An unprimed electrode always needs a greater potential difference from the anode before it will start to conduct.

DIRECT COUPLING

A recently developed counter, the Z302C, operates in chains without interstage amplifiers. It has the advantages of circuit simplification and low equipment cost. However, these advantages are gained at the expense of the maximum counting speed, which is 1000 pulses per second instead of the 4000 PPS possible with the Z303C and Z502S.

CIRCUIT DESIGN

All the tubes discussed require careful circuit design. In particular, the pulse amplitudes and durations must be within the limits given in the data sheets, otherwise the glow may not be transferred at all, may step in the wrong direction or, alternatively, the required counting speed may not be attainable. It is important to use the correct voltages, since potential differences underline every aspect of circuit operation.



Integrator pulse drive

SIMPLE VALVE MEASUREMENTS

This is the concluding article of a series which have been published in Outlook over the past year dealing with experiments for the examination of the properties and behaviour of thermionic valves. These experiments include measurements from which the characteristic curves of various types of valves may be plotted.

PENTODE

The pentode or five-electrode valve has three grids — a control grid (g_1) and screen grid (g_2) which perform the same functions as the corresponding grids of a tetrode, and a suppressor grid (g_3) located between the screen grid and the anode. The suppressor grid is usually connected to the cathode. See Fig. 13.

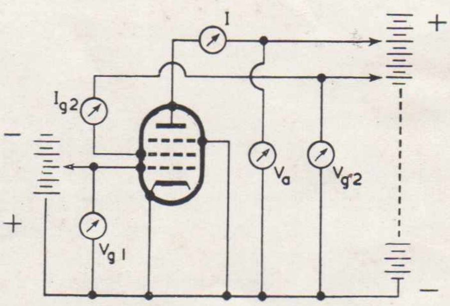


Fig. 13.—Basic Connections of a Pentode

As its name suggests, the suppressor grid is intended to suppress the flow of secondary electrons from the anode to the screen grid. It operates in the following manner:

The suppressor has a very open mesh and, therefore, has but little influence on the high-energy electrons which have already passed through the control grid and screen grid. These electrons, therefore, pass through the suppressor grid and are collected by the anode to form the anode current.

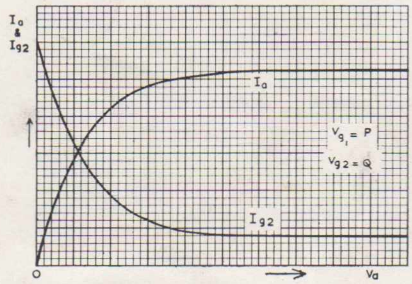


Fig. 14.—General Form of I_a/V_a and I_{g2}/V_a Characteristics of a Pentode

But, because the supressor grid is at cathode potential, and thus at a negative potential with respect to the anode, it repels the low-energy secondary electrons emitted by the anode. The secondary electrons therefore return to the anode, and the depression seen in the I_a/V_a characteristic of the tetrode does not occur in the characteristic of the pentode.

The typical form of I_a/V_a characteristic for a pentode at constant V_{g1} and V_{g2} is shown in Fig. 14, together with the corresponding I_{g2}/V_a curve. A complete family of I_a/V_a curves for a typical pentode is reproduced in Fig. 15.

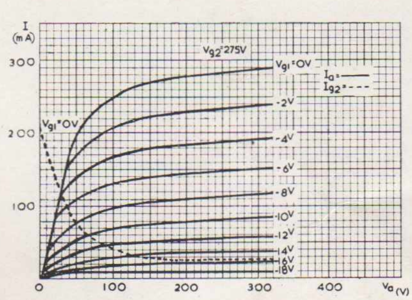
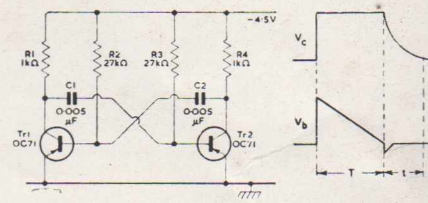


Fig. 15.—Family of I_a/V_a Characteristic Curves of a Typical Pentode

AMATEUR EXPERIMENTERS COLUMN

MULTIVIBRATOR



This circuit will be recognised as being similar in form to the familiar thermionic valve multivibrator. The frequency of operation is controlled by the discharge of C1 through R3 and C2 through R2, and is approximately equal to 0·77/CR. Where C in farads is 5×10^{-9} and R in ohms is 27,000, the frequency of operation of this circuit is therefore about 5·7kc/s.

Ideally the collector waveform provided by the multivibrator is square, and is obtained by switching the transistor from the bottomed (or collector current at saturation) condition to the cut-off (low collector current) condition. The collector voltage in the bottomed state is approximately zero and in the cut-off state it is approximately equal to the collector supply voltage.

The circuit is free-running and commences to operate as soon as it is switched on.

The accompanying illustration shows the actual waveforms. Assuming an initial condition where Tr1 is on and Tr2 is off, then as C1 charges, the base of Tr2 goes negative until Tr2 conducts. Regenerative switching occurs and Tr1 is now off and Tr2 on. C2 now charges and the base of Tr1 goes negative until Tr1 conducts, when the cycle starts all over again.

The period T is determined by the time taken by C1 (or C2) to discharge. The discharge of C1 takes place mainly through R3, but C1 also has to supply a leakage current $I_{c(o)}$ to the base of the cut-off transistor Tr2, the effect being to reduce the period T. The temperature dependence of $I_{c(o)}$ means that the frequency is somewhat temperature dependent. The time t for the collector to return to the supply voltage after the transistor is cut off depends on the time required by C1 to charge through R1.

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