THE
# RADIO CONSTRUCTOR
RADIO · TELEVISION · ELECTRONICS · AUDIO

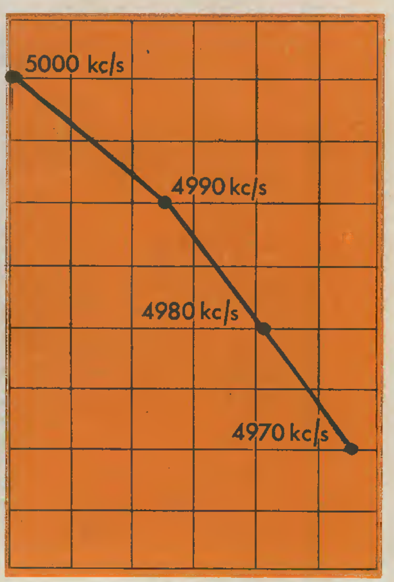
VOL. 22 NO. 8

MARCH 1969

3/-

A DATA PUBLICATION

## 100/10 Kc/s Frequency sub-standard Units



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| 100 | 1/– | 1/3 | 2/6 | 3/3 | 4/6 | 15/– |
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| 100 | 8/6 | 10/– | 15/– | 45/– |
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| T5 | 8 | 2G382T | EQVT. | OC82 | 10/– |
| T6 | 8 | 2G344A | EQVT. | OC44 | 10/– |
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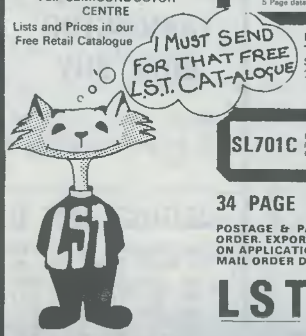

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**BC107/8/9 2/9d** each

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**UNIJUNCTION** including data

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5 Page data/details 2/6d.

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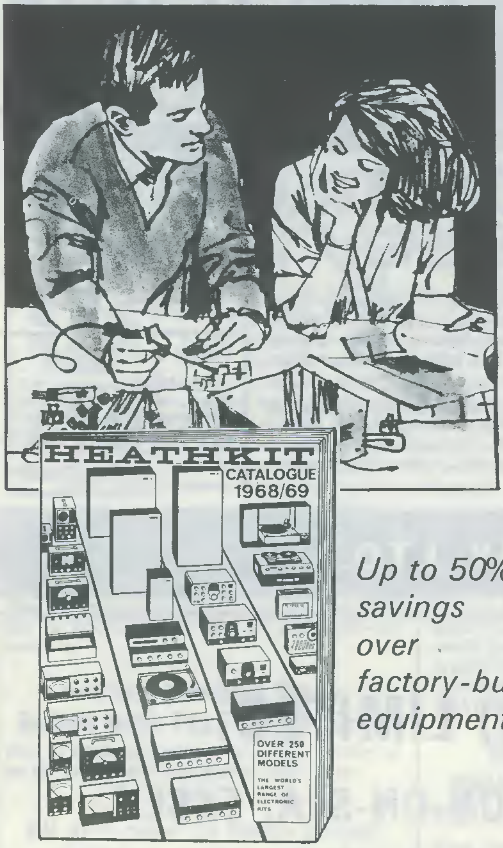

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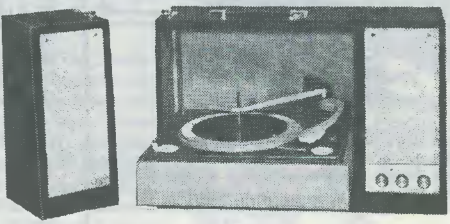

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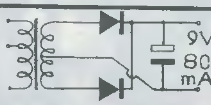

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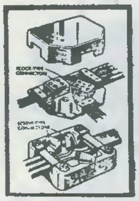

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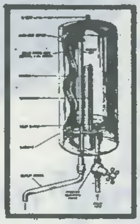

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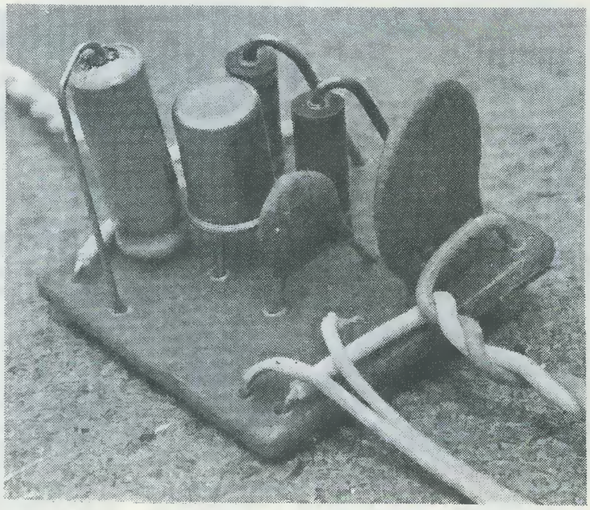
# LIGHT SENSITIVE OSCILLATOR

by

**N. A. SLAYMAKER, B.A.**



**A neat and simple low-cost a.f. oscillator whose frequency varies according to the light falling on a photoconductive cell.**

THIS SMALL, ONE-TRANSISTOR DEVICE CAN BE USED AS an "electronic eye" to mystify your friends, or as an amusing party game. Model makers and those interested in robot control will also no doubt find plenty of other uses for this adaptable device. The circuit is shown in Fig. 1.

Basically, it is a light sensitive oscillator. Variations in the light intensity falling on the ORP12 cadmium sulphide cell cause the frequency of the a.f. tone to vary, this tone being heard in a miniature earphone. By putting the ORP12 cell in a light-proof tube fitted with a lens as shown in Fig. 2, the device can be made very directional. This enables one to trace the source of a light while blindfolded, using the ORP12 assembly as an electronic eye. When heading towards the light the frequency steadily increases, whereas a wrong turn away from the light causes the frequency to decrease.

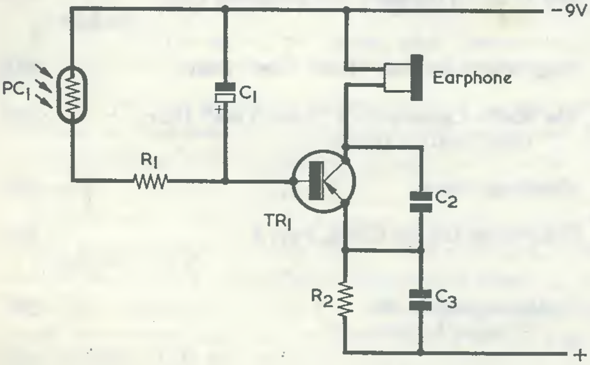


*Fig. 1. The circuit of the light sensitive oscillator*

The ORP12 is a cadmium sulphide photocell. It does not generate electricity when exposed to light, as most selenium or silicon "solar cells" do; instead its resistance varies with the light intensity. In complete darkness, the resistance will be very high, usually about 10M Ω, but it falls to a few hundred ohms when in bright sunlight.

## R-C OSCILLATOR

In this circuit, the cell is incorporated in the bias control network of a simple R-C oscillator. The 47k Ω resistor, R$_1$, limits the base current of TR$_1$ to a safe value if the cell is strongly illuminated. Most germanium p.n.p. low frequency transistors will work well in this circuit; a cheap "surplus" type may also be tried. enabling the cost of the unit to be kept very low.

The earphone may be any small magnetic type (not a crystal type, which would not provide a d.c. path for the

### COMPONENTS

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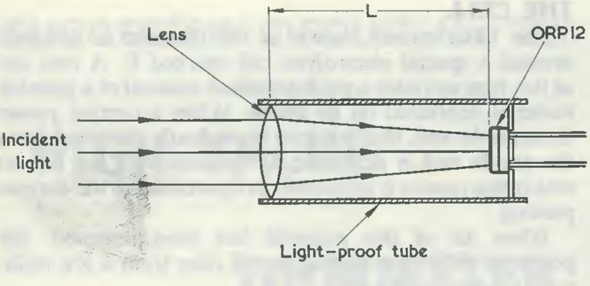
|---|---|
| *Resistors* | |
| R$_1$ | 47kΩ $\frac{1}{4}$ watt 10% |
| R$_2$ | 1.2kΩ $\frac{1}{4}$ watt 10% |
| *Capacitors* | |
| (All working voltages 9 or more) | |
| C$_1$ | 2μF electrolytic |
| C$_2$ | 0.02μF miniature disc ceramic |
| C$_3$ | 0.1μF miniature disc ceramic |
| *Transistor* | |
| TR$_1$ | germanium p.n.p. l.f. transistor (e.g. OC71, OC72 or "surplus" type) |
| *Photocell* | |
| PC$_1$ | ORP12 |
| *Earphone* | |
| Medium impedance magnetic earphone (see text) | |
| *Battery* | |
| 9-volt battery type PP3 or similar | |



L – slightly less than focal length

*Fig. 2. Mounting the ORP12 in a light-proof tube fitted with a lens considerably enhances directional sensitivity*

collector current of $TR_1$). The earphone employed initially was a balanced armature type with a d.c. resistance of 30 Ω. As this was rather bulky, a miniature earphone with a resistance of 400 Ω was next checked and was also found to work satisfactorily in the circuit. Further tests indicated that the oscillator will operate with any medium impedance earphone provided its resistance is 30 Ω or more.

The two resistors may be ¼ watt, and the capacitors require a working voltage of 9 volts or more only. In consequence the whole unit may be made very small, should this be desired.

Current consumption from the 9-volt battery varies with the illumination of the ORP12, but on average it is of the order of 3mA.

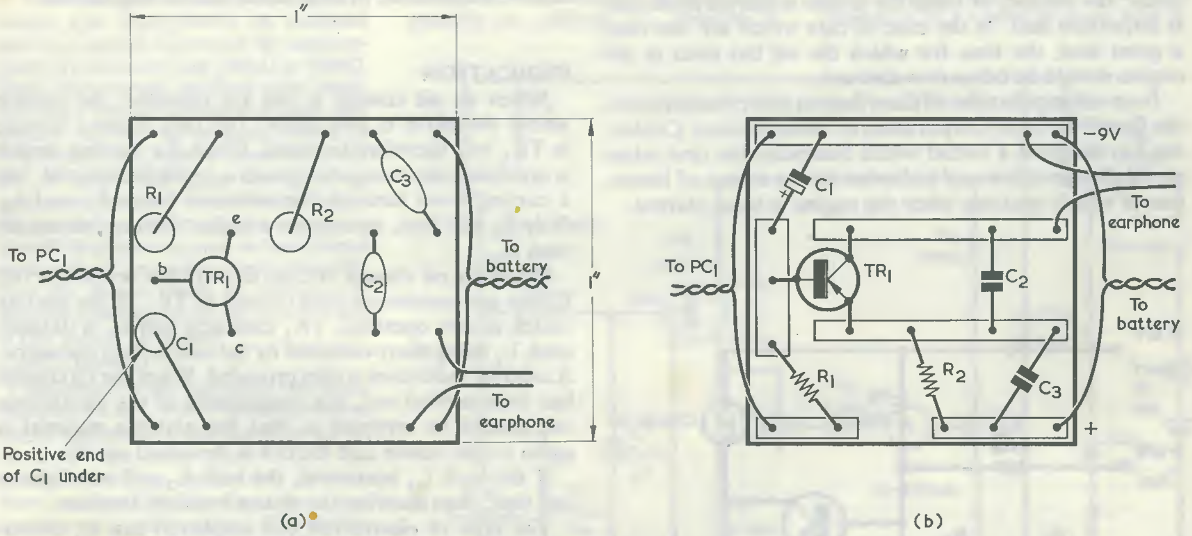
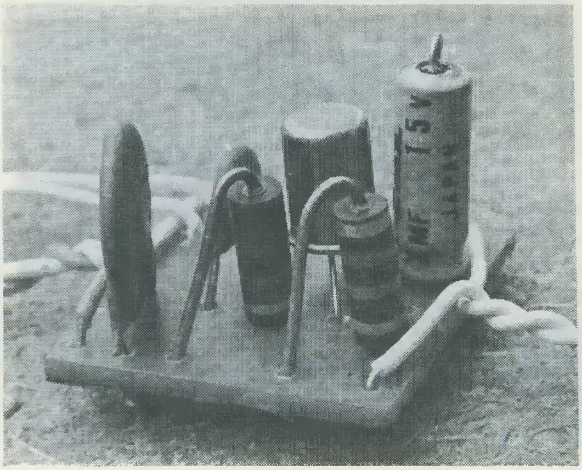


*Fig. 3 (a). The oscillator may be conveniently assembled on Cir-Kit. This view shows the components side of the board*
*(b). The conductor side of the Cir-Kit board*

## CONSTRUCTION

The circuit can be built up on a small piece of printed circuit board or Veroboard. A suitable layout, which can be built very quickly using Cir-Kit, is shown in Figs. 3 (a) and (b). (Cir-Kit is available from Henry's Radio or Electroniques.) An on-off switch could also be mounted on the board if desired but this was thought hardly necessary with the prototype since the battery clip can easily be removed. A small 9-volt battery, such as the PP3, will have a long life when powering the oscillator.



*The appearance of the board with $C_3$ at the left*

The cell may be mounted near the focus of a small convex lens, as in Fig. 2. A cheap "magnifying glass" will provide a suitable lens. The focal length of the lens may be found by focusing the image of a distant object, such as some clouds, on to a piece of white card. The distance between the lens and the card is then the focal length. The cell should be initially mounted at about this distance; an increase in sensitivity may then be obtained experimentally by moving the lens slightly so that the whole of the light sensitive area of the cell is illuminated.

Readers will have their own ideas on how to use the unit. The cell may be concealed in a blindfold, which also hides a miniature earphone, to demonstrate a "psychic" third eye. Build it and try! ✱

# ELECTRONIC OIL CHANGE INDICATOR

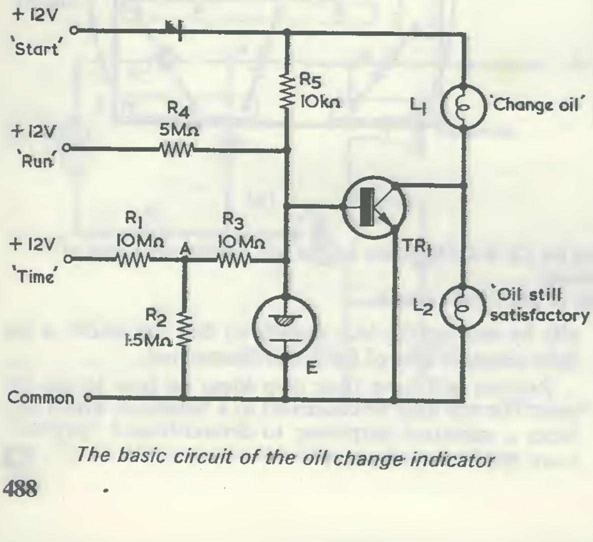
by

J. B. DANCE, M.Sc.

**Details of an American electronic device which computes the time when a car oil change is required.**

Motorists are advised by car manufacturers to change their engine oil each time they complete a certain mileage, since the oil will then be polluted and the additives used up to such an extent that the oil is no longer able to lubricate the engine efficiently. However, the distance travelled is not the only factor which determines the time at which oil should be changed. In particular, the number of times the engine is started from cold is important and, in the case of cars which are not used a great deal, the time for which the oil has been in the engine should be taken into account.

In an attempt to take all these factors into consideration, the Bissett-Berman Corporation of Santa Monica, California has designed a circuit which computes the time when an oil change is due and indicates this by means of lamps, one of which operates when the engine is being started.



*The basic circuit of the oil change indicator*

## THE CELL

The basic circuit shown in the diagram is designed around a special electrolytic cell marked E. A new cell of this type contains a predetermined amount of a platable material deposited on its anode. When a current passes through the cell, this material is gradually dissolved from the anode and is deposited at the cathode; the rate at which this occurs is accurately proportional to the current passing.

When all of this material has been removed, the potential difference across the cell rises from a few millivolts to about one volt.

## THE CIRCUIT

In the circuit the connection marked "Time" is always connected to the +12 volt supply, no matter whether the car is being used or not. The potential at point A is only about 1.5 volts and this drives a very small current through $R_3$ and through the cell. This small current enables the cell E to account for the total time the oil has been in the car.

The second connection (marked "Run") is connected to the +12 volt supply only when the engine is running—or, to be precise, when the ignition key is turned. This results in a much larger current flowing through the cell E during the time the engine is being used.

The third connection (marked "Start") is connected to the +12 volt supply only during the time the starter switch is operated, but the current is much larger than either of the other currents, since $R_5$ is much smaller than $R_4$ or $R_3$.

Thus the electrolytic cell can be used to add the contributions of the various currents, taking into account the relative importance of each factor in affecting the oil.

## INDICATION

When an oil change is not yet required, the voltage across the cell E is very small. The base current flowing in $TR_1$ will therefore be small. When the starting switch is operated, this transistor passes a negligible current, but a current flows through the indicator lamps $L_1$ and $L_2$. Only $L_2$ will light, since it has a higher filament resistance than $L_1$.

When an oil change is due, the voltage across the cell E rises and produces a base current in $TR_1$. If the starting switch is now operated, $TR_1$ conducts and $L_1$ is illuminated, $L_2$ being short-circuited by the conducting transistor. A suitable indication is thus provided. When the oil change has been carried out, the connections of the electrolytic cell should be reversed so that the platable material is again on the anode and the cell is then used again.

If the bulb $L_1$ burns out, the bulb $L_2$ will not light at any time, thus showing the system requires attention.

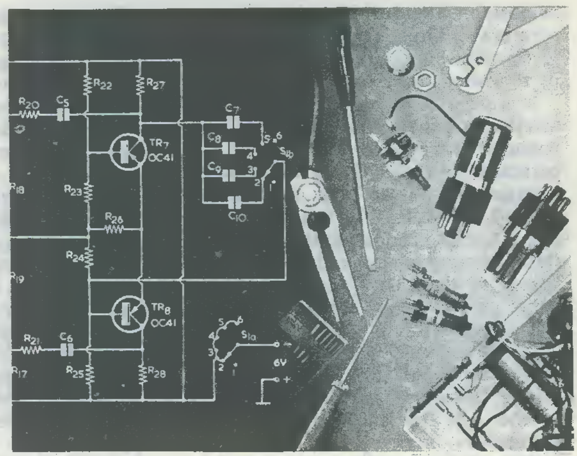
The type of electrolytic cell employed can be chosen according to the type of car and the type of oil used. If, for example, a long life oil is employed, a cell with a relatively large amount of the platable material should be used so that the oil change will not be indicated so early as with the type of cell used with ordinary oils.

It is interesting to note that electrolytic cells of this type have a wide range of other applications, for example in long delay timers and in very low frequency oscillators (giving a few oscillations per year).

## SUGGESTED CIRCUIT No. 220

# HIGH VALUE OHMMETER

### by G. A. FRENCH



THE EXCEPTIONALLY HIGH INPUT resistance of the insulated gate field effect transistor makes this semiconductor device extremely useful in the design and construction of sensitive measuring equipment. Typical examples occur, for instance, in previous articles in the "Suggested Circuit" series, these having described a voltmeter having a resistance of 10MΩ across its test terminals and a capacitance bridge capable of measuring capacitance to less than 1pF.* Both of these instruments employed insulated gate field effect transistors.

The ohmmeter discussed in the present article also incorporates an insulated gate f.e.t., and it is intended for measurement of resistance from 100kΩ to 50MΩ. Since the average medium cost multitestmeter usually provides reliable resistance readings up to some 100kΩ to 1MΩ only, the present instrument will be of particular value in servicing, constructional and experimental work. If carefully calibrated, its accuracy should be at least as good as that offered on the ohms ranges of a multi-testmeter, and the design could be modified to provide resistance readings above 50MΩ if this should be desired.

**THE CIRCUIT**

The circuit of the high value ohmmeter appears in Fig. 1. Power is obtained from an 18 volt battery, this coupling via $R_8$ to a 15 volt zener diode $ZD_2$. The stabilised voltage across this diode is then employed by the f.e.t. drain and source section of the circuit. The voltage across $ZD_2$ is also applied, via $R_7$, to a second zener diode, $ZD_1$, this stabilising at 6·2 volts.

The resistance to be measured is connected across the test terminals, these being normally short-circuited by push-button $S_2$, which opens when pressed. When $S_2$ is opened, a fraction of the 6·2 volts from $ZD_1$ appears on the non-earthy test terminal, the actual voltage at the test terminal depending on the resistance being measured and the setting of range switch $S_1$. This voltage is applied to the gate of the f.e.t. $TR_1$.

$TR_1$ functions as a source follower in a manner analogous to a valve cathode follower, whereupon its source takes up a potential dependent upon that at its gate. This potential is measured by $M_1$. It will be apparent that the voltage across the test terminals will increase as the value of the resistance under test increases. So also will the voltage above chassis at the gate and source of $TR_1$, whereupon it becomes possible to calibrate $M_1$ directly in terms of the resistance being measured. It is assumed, in the present application, that the gate of $TR_1$ has infinite resistance to its other electrodes, whereupon the circuit becomes capable of offering useful readings for very high values of test resistance.

The voltage across the test terminals depends upon the ratio between the resistance being measured and whichever of $R_1$ or $R_2$ is selected by $S_1$. If $S_1$ were in position 2 and the test resistance were equal to, say, 500kΩ, one-third of the voltage available from $ZD_1$ would appear across the test terminals. The same voltage (and hence the same reading in $M_1$) would be given with $S_1$

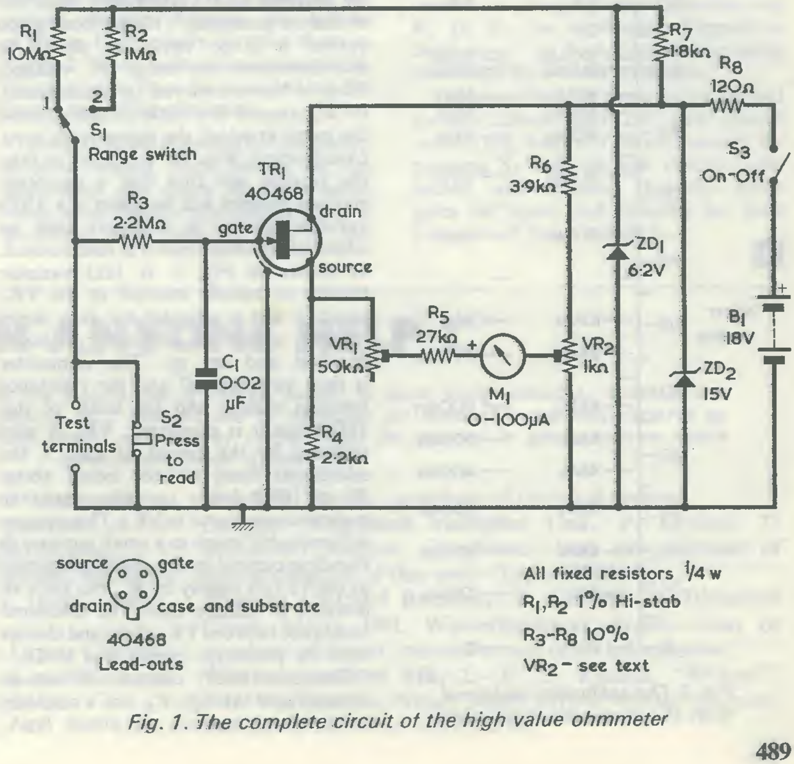


*Fig. 1. The complete circuit of the high value ohmmeter*

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*"Simple F.E.T. Voltmeter," July, 1968 issue; "Low Value Capacitance Bridge," November, 1968 issue.

in position 1 and 5MΩ across the test terminals. Thus, resistance readings given with $S_1$ in position 2 are multiplied by 10 when $S_1$ is set to position 1.

It is possible to break down the gate insulation of the f.e.t. if excessively high voltages are applied to it. With the particular f.e.t. specified, gate-to-source voltages should not fall outside the range 0 to —8. It is for this reason that $S_2$ is fitted and it protects the f.e.t. from static voltages which could possibly be passed to the gate whilst the resistor under test is being connected to the instrument. A small measure of protection is given also by $R_3$ and $C_1$, these helping to ensure that any short-term "spiky" static voltages are not passed to the gate via the non-earthy test terminal.

When there is zero resistance across the test terminals (as occurs before $S_2$ is pressed) the source of the f.e.t. takes up a potential which is positive of the gate. The function of preset resistor $VR_2$ is to offset this potential, and it is adjusted such that the meter reads zero under this condition. If $S_2$ is pressed whilst no resistance is connected across the test terminals, the gate of $TR_1$ takes up the full positive potential available from $ZD_1$. Pre-set resistor $VR_1$ is then set up such that the meter gives full-scale deflection. Thus, the meter reads zero for zero test resistance, and f.s.d. for infinite test resistance.

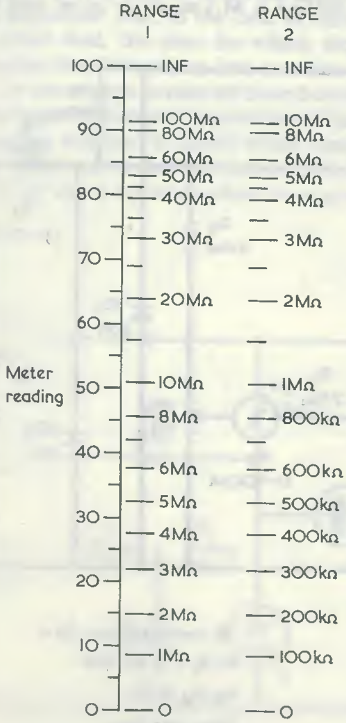


*Fig. 2. The calibration obtained with the prototype instrument*

The reason for supplying the $R_1$, $R_2$ and test resistor network from the reduced voltage of 6·2 offered by $ZD_1$ is that higher voltages could cause the f.e.t. gate to go positive of its source, thereby exceeding the manufacturer's recommendation for gate-to-source voltage.

A slight saving in cost would have been achieved by replacing $ZD_1$ with a 1·2kΩ resistor, whereupon a voltage of 6 would still be available for the network comprising $R_1$, $R_2$ and the test resistor. This voltage would have a reasonable level of stabilisation due to the presence of $ZD_2$. On the other hand, it is desirable that the voltage available for the test resistor network be very reliably regulated whereupon, since a suitable diode for the $ZD_1$ position can be obtained for a few shillings only, it was considered reasonable to include the diode here.

The test resistance/meter reading calibration obtained with the prototype circuit is shown in Fig. 2, and it will be noted that the Range 2 resistance figures are exactly one-tenth of those in Range 1. Useful indications are given in Range 1 up to 50MΩ, above which figure the scale starts to become cramped. It must be emphasised that Fig. 2 is presented only as a *guide* to the performance that other ohmmeters made up to the circuit will offer. The gate-source transfer characteristics of different f.e.t.'s may well vary, and other ohmmeters should be calibrated individually.

Since it is difficult to predict the source potential which will be taken up by different f.e.t.'s when their gates are at chassis potential, $VR_2$ has been given rather a large value in order to accommodate the range of voltages likely to be encountered. In consequence, its adjustment is a little critical around the point at which the meter reads zero. Constructors who are prepared to take the trouble will find that a smoother zero-set control will be given if a 250Ω variable resistor in company with an added series fixed resistor is used instead, as shown in Fig. 3. A 1kΩ variable resistor is initially inserted in the $VR_2$ position and is adjusted for zero meter reading whilst the ohmmeter is being checked and set up. The ohmmeter is then switched off and the resistance between chassis and the slider of this 1kΩ resistor is measured. $VR_2$ is next replaced by the circuit of Fig. 3, the additional fixed resistor being about 50 to 100Ω lower in value than the resistance measured in $VR_2$. This process will probably result in a small increase in standing current in the chain completed to the 15 volt supply by $R_6$, but such an increase is unimportant. The measured resistance between $VR_2$ slider and chassis with the prototype circuit was 510Ω.

Rather a heavy current, of around 25mA, flows through $R_8$, and a similarly fairly heavy current, of about 5mA, flows through $R_7$. These currents result in both zener diodes being brought well on to the more horizontal parts of their characteristics. It should be added that accuracy may suffer if the ohmmeter is used with a battery whose voltage has fallen to 16·5 or less.

Provided that initial calibration has been carried out carefully, the ohmmeter should offer good long term accuracy. Both the transistor drain voltage and the reference voltage for the $R_1$, $R_2$ and test resistor network are regulated and these should not shift with time. The only "unknown quantity" in the measurement chain from the test terminals to the meter is the source-follower performance of the f.e.t. itself. However, the f.e.t. is operated at a low dissipation level and adjustments are available to cater both for the zero resistance and the infinite resistance ends of the scale. It would seem reasonable to expect a constant long term gate-source characteristic between these two extremes. Another possible long term cause of inaccuracy could be decreasing insulation resistance in $C_1$ and in any other insulation to chassis in the gate circuit components. Fortunately, it is possible to check this last point very simply at any time by merely changing the range switch from one position to the other whilst $S_2$ is pressed and no resistance is connected across the test terminals. If the insulation resistance is adequate there should not then be any significant change in $M_1$ reading for either position of $S_1$.

The prototype circuit has an arbitrarily chosen top resistance measurement of 50MΩ, since it is felt that this range would be more than adequate for normal experimental constructional and servicing work. If desired, nevertheless, it should be theoretically possible to extend the range to 100MΩ by having a 20MΩ resistor in the $R_1$ position, whereupon Range 1 readings become 20 times greater than Range 2 readings. This modification has not been checked by the writer in practice.

### COMPONENTS

Details of the fixed resistors are given in Fig. 1. It was found, with the prototype, that $VR_1$ needed no further adjustment after it had been initially set up, whereupon it could be housed within the case of the instrument. $VR_2$ needed very slight occasional adjustments to counteract drifts of the order of 1 to 2μA, and could be mounted on the front panel. This last comment also applies, of course, if the 250Ω variable resistor of Fig. 3 is used.

Both zener diodes should have a 5% tolerance on zener voltage, whereupon $ZD_1$ could be a Z6·2 and $ZD_2$ could be a ZL15, both of which are available from Henry's Radio Ltd.

Insulation in the gate circuit of $TR_1$ must be of a very high order, and both $S_1$ and $S_2$ must be good-quality components. Paxolin insulation is quite satisfactory here provided that surfaces are kept clean and dry. $C_1$ must be a good quality component and an excellent choice would be a Mullard polyester capacitor. These capacitors have insulation resistance in the order of tens to hundreds of thousands of megohms. Incidentally, the Mullard range uses preferred capacitance values, whereupon $C_1$ would require a value of 0·022μF.

The f.e.t. is an R.C.A. 40468 (available from Amatronix Ltd.). This is an n-channel depletion type. Very great care must be taken to prevent high voltages being applied to the gate during wiring up, and it should be remembered that such voltages can be present on the bit of an unearthed soldering iron. The author's approach to this problem is to wire the f.e.t. circuit connections to a 4-way transistor holder (suitable white nylon transistor holders are also available from Amatronix, Ltd.) and then fit the f.e.t. to this holder after all soldered connections have been carried out and wiring has been completed and checked. The case and substrate lead-out of the f.e.t. connects direct to chassis.

So far as switch types are concerned, $S_1$ and $S_3$ may be rotary or toggle, as desired. $S_2$ is a panel mounting push-button which opens when pressed. Alternatively, a spring-biased toggle switch may be used.

The 18-volt battery could be conveniently provided by two PP9 batteries in series.

## ASSEMBLY AND SETTING UP

The complete circuit can be assembled in a metal case which also forms the chassis.

It is important to note that $S_2$ must only be pressed *after* the resistance to be checked has been connected to the test terminals and the operator's hands have been removed. Similarly, it must be released *before* the test resistance is disconnected. A notice on the front panel should be appended to emphasise these points. It would be preferable to use insulated test terminals to guard against the risk of the non-earthy terminal being accidentally touched by a soldering iron or any wire or conductor which may carry a relatively high voltage. These precautions have to be observed because the non-earthy test terminal has a high impedance to chassis and any high voltage applied to it accidentally could cause breakdown of the f.e.t. gate insulation.

When construction is completed and wiring has been checked, the ohmmeter is ready for testing and setting up. Adjust $VR_1$ to insert full resistance and $VR_2$ to a central position. Switch on, then check that the correct direct voltages appear across $ZD_1$ and $ZD_2$. This guards against the not-too-rare possibility of their being wired into circuit wrong way round!

Adjust $VR_2$ for zero reading in the meter. Press $S_2$ and adjust $VR_1$ for f.s.d. indication in the meter. Repeat the adjustments in $VR_2$ and $VR_1$, then finally adjust $VR_2$. Next, press $S_2$ again and check the meter reading for both positions of $S_1$. If there is no significant change in meter reading, it can be assumed that the insulation in the gate circuit is satisfactory, whereupon calibration may commence.

A calibration chart similar to that shown in Fig. 2 should be made up by noting the meter readings for known values of resistor. Readers will have their own ideas on the procedure here, and the process is simplified in the present instance because the figures in Range 1 are exactly 10 times those in Range 2. When calibration is completed, the chart may then be mounted on the front panel of the ohmmeter.

The procedure for using the ohmmeter is quite simple. First switch on the instrument and check that the meter reads zero, slightly readjusting $VR_2$, if necessary. Then press $S_2$ with no test resistance connected and ensure that the meter gives full-scale deflection. If it does not, the battery may require replacement. (Incidentally, a run-down battery can cause the meter to read *more* than f.s.d.). Then connect the resistance to be measured across the test terminals, pressing $S_2$ only *after* the resistance has been connected and the operator's hands have been removed from the terminals. $S_1$ may be adjusted whilst $S_2$ is depressed. After taking the reading, release $S_2$ *before* disconnecting the resistor from the test terminals.

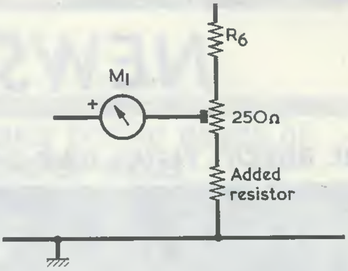


*Fig. 3. $VR_2$ may be replaced by a lower value variable resistor, if desired. The procedure needed for finding the value of the added resistor is described in the text*

Insulation resistance in capacitors can also be tested with the ohmmeter. If electrolytic capacitors are to be checked, their positive lead-outs should be connected to the non-earthy test terminal. With capacitors above 1μF or so, the ohmmeter will take some time to reach its final reading due to the delay incurred in charging the capacitor via $R_1$ or $R_2$, as applicable. Capacitors must *always* be discharged before being connected to the test terminals.

Occasionally, say once every several months, check that the gate circuit insulation has not deteriorated by pressing $S_2$ with no test resistor connected, and ensuring that the meter gives the same f.s.d. reading for both positions of range switch $S_1$.

# CAN ANYONE HELP ?

*Requests for information are inserted in this feature free of charge, subject to space being available. Users of this service undertake to acknowledge all letters, etc., received and to reimburse all reasonable expenses incurred by correspondents. Circuits, manuals, service sheets, etc., lent by readers must be returned in good condition within a reasonable period of time*

**Bush Receiver Type PB61.**—R. Batty, 2 Manor View, Halfway, Sheffield SI9 5GG—loan or purchase of the circuit diagram for this a.c. mains operated receiver.

**Conversion—TV to Oscilloscope.**—M. Cawson, Meadow Down, Tichborne Down, New Alresford, Hants.—any details of such a conversion.

**R1155 Receiver.**—B. Dunn, 8 Lancaster Drive, Clayton-le-Moors, Accrington, Lancs.—details of modifications and any other information, circuit diagram, etc.

**Collins TCS 12 Receiver.**—R. Burrows, 100 Fell Lane, Keighley, Yorks.—purchase of circuit diagrams.

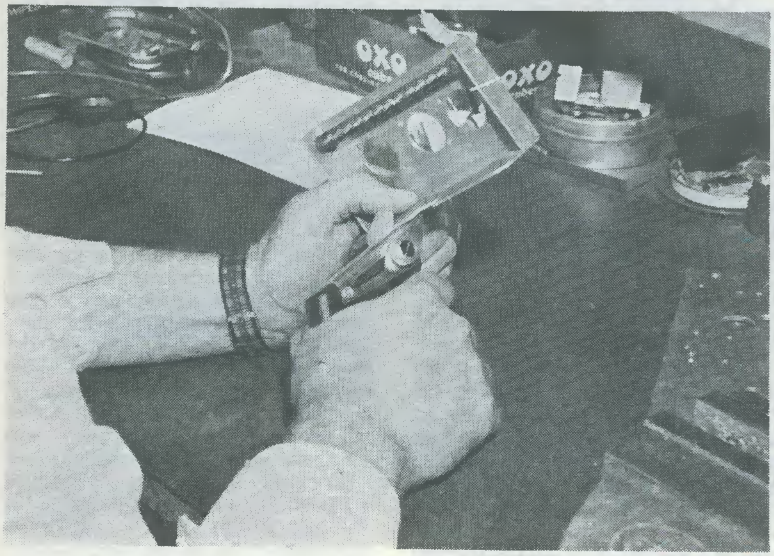
**Labgear Wide-Band Multiplier Unit.**—P. Leydon, 37 Barnwood Avenue, Gloucester—loan or purchase of circuit diagram of this unit—Type E5026.

**Marconi CR150/4 Receiver.**—P. Garrett, 24 Tibberton Close, Merry Hill, Wolverhampton, Staffs.—loan or purchase of circuit, manual or any other information.

**Wireless Set B44 Mk. 2.**—P. D. Russell, "Wyford", P.O. Van Reenen, Natal, South Africa—circuit diagram, manual or any other information.

# NEWS . . . AND .

## THE GOSCUT PISTOL-GRIP SHEAR



*The new Goscut shear introduced by R. A. Stephen & Co. Ltd., Miles Road, Mitcham, Surrey, has numerous uses in the workshop and will cut aluminium alloy chassis for terminal strip without distortion of the metal. To cut out a slot as shown, the blade is used to make a diagonal cut, or for thinner slots, to trim along the side of the insertion.*

The Goscut single-handed shear is only 6in. long and is adjustable to cut almost all sheet materials from paper to steel. The shear is named after its inventor, Anthony Goss (41), a former steeplejack.

It has three interchangeable blades:

(a) the general purpose blade which cuts laminated plastic sheeting in $\frac{1}{16}$in. thicknesses, $\frac{1}{8}$in. hardboard, melamine-surfaced or plain, thermoplastic and other rigid floor tiles, p.v.c. sheet and guttering, and many other tough materials.

(b) the metal blade which cuts mild steel to 19 s.w.g. (0·040in. or 1·0mm.) and heavier gauges of softer metals such as aluminium and copper, to 16 s.w.g., 0·062in., 1·6mm. Zinc, brass, tinfoil and metal alloys of many kinds, perforated metal sheet, expanded metals, grids and meshes, etc., also come within the capacity of the metal blade.

(c) the third blade which cuts circles and shapes in the plastic sheets and hardboard described above to 1$\frac{1}{2}$in. radius, and in metal sheet of 0·032in., 0·8mm., to 4in. radius.

In general the Goscut will cut all the thicknesses of sheet material listed above, except those kinds which shatter, such as glass and pottery.

The blade bears down through a slot in a flat surface, so that the tool provides its own anvil or workbench. Close support at the point of cut prevents distortion or fracture of the material and leaves a clean-cut edge.

Adjustment of the slot width enables materials of varying thicknesses below $\frac{1}{8}$in. to be cut. Cutting speed is about 30 seconds a foot run or a little longer for the heavier gauges of metal. The tool weighs about 8 oz. with a blade inserted. Blade changing takes less than a minute. The retail price of the Goscut complete with three blades is 37s. 6d.

## FARADAY MEDAL AWARD

The Council of the Institution of Electrical Engineers has made the 47th award of the Faraday Medal to Dr. Philip Sporn, C.Eng., F.I.E.E., "for his outstanding pioneering work in the development of the generation, transmission and distribution of electrical power."

The Faraday Medal is awarded not more frequently than once a year, either for notable scientific or industrial achievement in electrical engineering or for conspicuous service rendered to the advancement of electrical science, without restriction as regards nationality, country of residence, or membership of the Institution.

Dr. Philip Sporn, C.Eng., F.I.E.E., was born in Austria in November, 1896, and became an American citizen in 1907. He was educated in the United States and from 1917 to 1918 did postgraduate work in electrical engineering at the University of Columbia. Dr. Sporn subsequently held many important positions and has had a most brilliant career.

The awards which Dr. Sporn has received include the Edison Medal in 1945, the John Fritz Medal in 1956 and the Conservation Award from the US Department of the Interior in 1960.

## RADIO AMATEUR LEADS AFRICA EXPEDITION

David Dunn, 25-year-old senior design draughtsman with Hydraulic Machinery (Great Britain), is leading a trans-Africa expedition.

During an eight-month safari through North, East and South Africa, the team will study the reliability of low power short wave radio communications. They will also carry out geological investigations in the Rift Valley area of East Africa.

A bachelor, Mr. Dunn is a radio amateur (call sign GW3XRM) and will make daily contact en route with a radio operator based at Cardiff University. The University and the Students' Union have provided grants for the provision of the radio equipment, which will be on board the ex-Army Commer cross country truck the team have bought for £100 to take them on the 12,000 mile journey.

Application has been made for radio transmitting licences from each country the team visits, and Mr. Dunn hopes to meet some of the radio amateurs he has "worked" from time to time.

# . . . COMMENT

## FAIRCHILD'S RAPID GROWTH

Although it has only been established ten years, SGS-Fairchild is well known throughout Europe as a leading supplier of semiconductor devices. Its rapid success, and indeed its origins, are due to one of the most significant electronic developments of the century, the planar process for producing transistors.

Before this process was developed, a production difficulty common to all types of transistors was exposure of the wafers of semiconductor material to the external atmosphere during the manufacturing process. This gave rise to surface contamination and consequent device instability. The planar process overcomes this hazard by using wafers of silicon and first coating the wafer surface with a hard glass-like layer of silicon dioxide. This layer, formed by diffusion under intense heat (1200°C), protects the wafer surface and thus prevents contamination. The semiconductor junctions which constitute the device are afterwards formed by further diffusions underneath the layer and are therefore never exposed to contamination.

Not only does the planar technique produce better transistors and diodes, it also enables several devices including resistors and capacitors, to be diffused on a "chip" of silicon about 50 thousandths of an inch square, so that whole circuits can be formed on an area no larger than a pinhead. Therefore the planar semiconductor diffusion process opened the way for the semiconductor integrated circuit, or microcircuit as it is often called. It is still the basis of all microcircuit production methods.

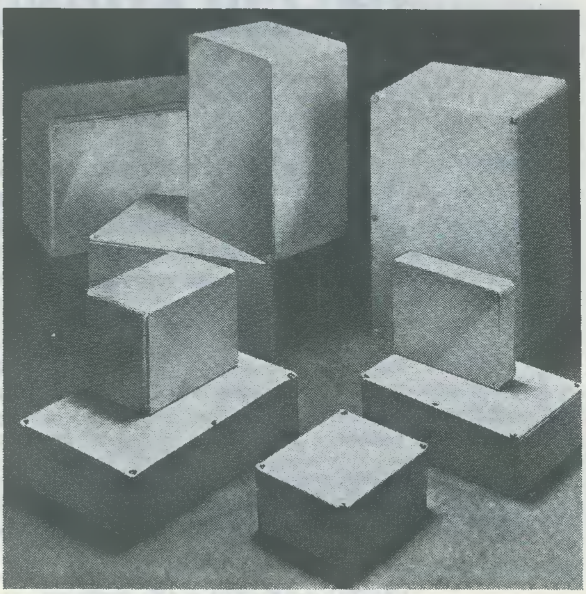
The planar technique was developed about ten years ago at the research laboratories of the Fairchild Camera and Instrument Corporation of America.

It soon became clear to the SGS-Fairchild management that if the new technology and its potential markets were to be fully exploited, the Company would have to be organised on an international basis. They foresaw the vital role semiconductors would play in the economy of each national market, and realised that separate national organisations would be needed to meet individual market requirements.

Therefore the Company created a series of marketing teams in the main countries of Europe staffed entirely by nationals of the countries concerned, the intention being that teams would develop into autonomous companies, depending on their rate of growth. In 1962, SGS-Fairchild Limited was formed in the UK.

As soon as each national company became established, the second step towards autonomy—the setting up of manufacturing facilities—was undertaken. In the case of the British company, progress towards self-sufficiency was accelerated by the construction of a temporary plant at Ruislip, Middlesex, early 1963.

## ELECTRONIQUES EXTEND RANGE OF DIE-CAST BOXES

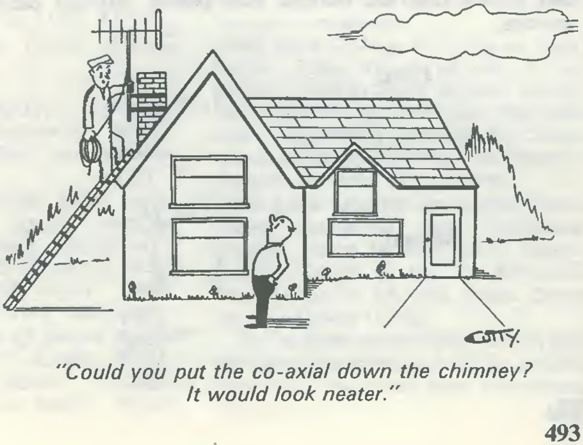


The Electroniques range of die-cast boxes has been extended from five to nine sizes. The complete range now extends from 4 x 3 x 1in. to 11 x 7 x 6in.

The new larger sizes incorporate the slot guide system used on the original range. The guides are unique to Electroniques boxes. They allow greater mounting flexibility, since printed circuit boards or screens can be inserted on which additional components can be mounted, thus increasing the component density.

The four larger sizes, which are not available elsewhere, will prove useful in housing equipment for which fabricated steel cases are currently used. The die-cast construction offers ruggedness and lightness, ease of machining and economical price. The screening properties will be valuable in some applications.

Further enquiries to: Electroniques, Edinburgh Way, Harlow.



*"Could you put the co-axial down the chimney? It would look neater."*

# QUICK PARALLEL-R CALCULATIONS

### by A. L. GRASSO

**A neat mathematical trick eases the problem of finding the total resistance of several resistors in parallel. It is particularly helpful if the number of resistors is three or more.**

THERE IS ONE FORMULA THAT TECHNICIANS AND amateurs particularly dislike among the multitude of formulae in our branch. That is the equation for two resistors in parallel,

$$R_x = \frac{R_1 R_2}{R_1 + R_2}$$

or, in the case of three,

$$R_x = \frac{R_1 R_2 R_3}{(R_1 R_2) + (R_1 R_3) + (R_2 R_3)}$$

One way of avoiding it is by assuming a certain voltage across each resistor. By means of $I = \frac{V}{R}$ calculate the current that goes through each resistor (call the currents $I_1$, $I_2$, etc.) and then sum up to find the total current going through the resistors.

If we then divide the assumed voltage by the total current, we will find the resultant resistance of the resistors in parallel.

## EXAMPLE WITH TWO RESISTORS

Suppose we have two resistors in parallel of 75Ω ($R_1$) and 150Ω ($R_2$) respectively, and we want to know the resultant resistance ($R_x$) of the two. We proceed in the following manner.

Let us assume for our convenience a voltage of 150V, and let us find the current that passes through each resistor.

First,

$$I_1 = \frac{V}{R_1} = \frac{150V}{75\Omega} = 2A.$$

Second,

$$I_2 = \frac{V}{R_2} = \frac{150V}{150\Omega} = 1A.$$

Now let's sum up $I_1$ and $I_2$ to find the total current ($I_t$) passing through $R_1$ and $R_2$.

$$I_t = I_1 + I_2 = 2A + 1A = 3A.$$

By applying $R = \frac{V}{I}$ we can obtain $R_x$ for the two resistors $R_1$ and $R_2$ as follows:

$$R_x = \frac{V}{I_t} = \frac{150V}{3A} = 50\Omega.$$

Any assumed voltage can be used for this calculation, but the easiest way is by using a voltage of equal figures to the highest resistor.

## USING A SLIDE RULE

If the reader owns and can use a slide rule, so much the better. In this way, the calculation of $R_u$ for $R_1$, $R_2$ and $R_3$ in parallel won't take more than 15 seconds, and the extraordinary practicability of this method can be fully appreciated.

Let's say that $R_1 = 40\Omega$, $R_2 = 160\Omega$ and $R_3 = 200\Omega$. We automatically choose the value of $R_3$ as our assumed voltage, that is 200V; therefore we know already that $I_3$ is equal to 1A.

Using the slide rule we find right away the values of $I_1$ and $I_2$ by dividing 200V by $R_1$ first, and $R_2$ after. Mentally sum up $I_1$, $I_2$ and $I_3$, and find the value of $R_x$ on the slide rule by dividing the assumed voltage (V) by the $I_t$.

First,

$$I_1 = \frac{V}{R_1} = \frac{200V}{40\Omega} = 5A.$$

Second,

$$I_2 = \frac{V}{R_2} = \frac{200V}{160\Omega} = 1.25A.$$

We know that $I_3$ is 1A so,

$$I_t = I_1 + I_2 + I_3 = 5A + 1{\cdot}25A + 1A = 7{\cdot}25A.$$

Therefore, we may say,

$$R_x = \frac{V}{I_t} = \frac{200V}{7.25A} = 27.6\Omega$$

And that's it!

# Q S X

## by L. SAXHAM

(All times GMT)

**A report on the stations – both amateur and broadcast – that may be logged by the s.w.l. on the various short wave bands; compiled by a Dx'er whose QTH is located near the S. Suffolk coast.**

### ● Topic

Most s.w.l's usually progress from the construction and operation of a simple "straight" or t.r.f. receiver to the purchase of an inexpensive communications superhet. In practice these do not display those qualities desired by the discerning operator and to overcome this, recourse must be had to the construction and operation of various items of ancillary equipments.

The first essential, to the writer's mind, is an aerial tuning unit and this is easily and cheaply constructed, its use making the long wire aerial—that most used by s.w.l's—part of a resonant circuit and providing maximum transfer of energy over a wide frequency range. (See page 10, August, 1968 issue).

The next unit to construct is a preselector. This is nothing more than an outboard tuned r.f. stage that will pre-tune and boost the desired signal, passing this to the aerial input of the receiver. Its use will largely overcome inherent faults in a superhet receiver produced to a low price specification—lack of sensitivity, selectivity and second channel interference. The unit should exhibit as low a noise level as possible and be capable of producing as much gain, *with stability* as can be obtained. (See page 282, December 1968).

To still further enhance the selectivity of the receiver a Q-Multiplier should be constructed. When connected into circuit, and correctly aligned, a Q-Multiplier will improve the selectivity out of all recognition. Transmissions that were formerly almost inaudible, due to strong adjacent transmissions, will now become intelligible. The unit should be capable of being switched in or out of circuit and should present as little insertion loss as possible. A correctly matched and aligned Q-Multiplier will provide a selectivity response equal to a crystal filter. (See page 102, September 1968 issue).

The acquisition of a crystal controlled frequency sub-standard unit allows the operator to align his receiver dials to accurate frequency readings. Most crystal standards oscillate at a fundamental frequency of 100 kc/s and produce harmonics of this frequency throughout the range of the average communications receiver. The additional inclusion of a switchable 10 kc/s multivibrator in the circuit allows the operator to sub-divide the 100 kc/s points into 10 kc/s markers and this latter facility is of paramount importance when calibrating the *bandspread* dial over a particular Amateur or Broadcast band.

At this juncture, it is usual to draw up a series of graphs using bandspread dial readings against the marker points. Providing the graphs—using suitably sized graph paper scaled in tenths to the inch—have been prepared with some forethought and care, frequency interpolation will be found to be quite accurate. Before preparing graphs however, care should be taken to ensure that the receiver and the ancillary units have attained their stable working temperatures. A further point to note, when taking bandset and particularly bandspread dial readings, is that of parallax. Dials should always be read from the same visual angle. To obtain pin-point readings, the writer uses magnifying lenses mounted external to the receiver, and directly in front of, the bandset and bandspread dials. Down the vertical axis of these lenses is a thin hair-line graticule which must line up with the receiver graticules prior to a frequency reading being taken.

### ● Amateur Bands

Conditions on these bands have varied very greatly over the period which this report covers. Very little time was spent on the higher frequency bands and most of the Dx, at least for the writer, was found on Top Band (1·8 Mc/s). For a change—anything to make life harder!—the mode of reception was limited to c.w.

**14 Mc/s**

**CW:** CR7HU, JA2IG, 2I0D, KP4GI, LU2ACH, PY1CSN, 7AHO, 6Y5UC and 7P8AB.

**7 Mc/s**

**CW:** CO2BB, K6AHV, PY7AOR, 7AWD, PZ1DE, VE1AWB, 3BWY, 3EAQ, 3WTV, W4BVV and W6RW.

**1·8 Mc/s**

**CW:** DL1CF, GM3BGW, 3FSV, 3IAA, 3OXX, GW3HGL, 3XJC, HB9CM, K1PBW. (1802 kc/s 0500GMT), K2GAL, 8BBI, KV4FZ, OK1AOR, 1ATP, 1AWN, 1FVV, 1JOE, 1KAY, 1KRS, 1KYS, 1STU, 1VC, 1WT, 2HZ, 2ZU, 3CHR, 3KAG, 3KIC, OL1ALM, 2AKS, 2AIO, 6AIN, 6AKO, 6AKW, 7AKS, 9AIR, PA0DC, 0SNG, VE3QU, W1BB/1 (1803 kc/s 0455), W2BP (1803 kc/s 0620), 2EQS, 2FJ, 2IU, 3FET, 3IN, 3TV, 7NMJ, 8ANO and W8JIN.

### ● Broadcast Bands

**3277 kc/s 1635** R. Kashmir, India, with sitar music. Clear channel at this time.

**3339 kc/s 1940** R. Tanzania, Zanzibar, Arabic type songs, QRM from Mozambique on 3338 kc/s.

**3395 kc/s 0125** YVOK Merida, Venezuala, with talk in Spanish.

**3883 kc/s 2040** CR4AA R. Clube de Cabo Verde, music programme.

**4680 kc/s 0245** HCWE1 R. Nacional Espejo, Ecuador, with identification.

**4800 kc/s 1520** AIR Hyderabad, India, current affairs talk in English.

**4820 kc/s 1530** VUM Madras, India, drama programme. 6 "pips" at 1530 then "This all All India Radio" and news in English.

**4823 kc/s 1600** Hanoi, Vietnam, female speaking in vernacular. Heard several times, taped.

**4865 kc/s 0235** PRC5 R. Club do Para, Brazil, with Latin American music.

**4872 kc/s 0230** TGQH Santa Cruz, Guatemala, with identification.

**4900 kc/s 1950** Conakry, Guinea, with African type music.

**4904 kc/s 2025** Fort Lamy, Chad, with talk in French.

**4905 kc/s 2020** R. Peking, China, with talk in dialect.

**4907 kc/s 1550** R. Cambodia, (Phnom-Penh), with female singer and childrens choir. Announcements in dialect then Military band. Heard several times, signal never very strong, best, SINPO 33333.

**4910 kc/s 0430** HCMJ1 Emis. Gran Colombia, Ecuador, with identification.

**4980 kc/s 2000** Accra, Ghana, with African drums and news in English.

**4985 kc/s 1500** R. Malaysia, with "Your Newsreel Magazine" in English.

**6160 kc/s 0258** HJKJ Bogata, Columbia, with Marimba chimes and identification.

### ● For Beginners

For broadcast bands beginners, the following stations would serve as possible "targets." They are not "dead-easy" to receive but, on the other hand, they are not over difficult given the right conditions.

**3883 kc/s** CR4AA R. Clube de Cabo Verde, Cape Verde Islands. Listen around 2000 to 2100 for best results. Identification—5 notes on Marimba and "Aqui Praia Estacao de Ondas Curtas do Radio Clube de Cabo Verde." Power—variable 0·5 to 5kW.

**6250 kc/s** EAJ205 Emisora de Santa Isabel, Fernando Poo, Equatorial Guinea. Listen 1800 to 1945. Identification "Desde la Isla de Fernando Poo, transmite EAJ205 Radio Santa Isabel". Power 10kW.

Try to listen to this latter station and see how you make out. I'll be writing about this frequency next time round (May).

# MINI-RADAR— A NEW INDUSTRIAL TOOL

A NEW INDUSTRIAL AND RESEARCH TOOL IS ANNOUNCED by James Scott (Electronic Engineering) Limited, which may well revolutionise industrial measurement techniques.

The instrument is a miniature battery-operated radar, which can measure velocities of up to 100 m.p.h. where a body is travelling in a straight, angled, or curved path, and which in addition can measure high rotational speeds of the order of 1 million r.p.m. The device, known as the 'Allscott Mini-Radar Type MRJ5' (see illustration), provides a means of measurement, the accuracy of which is limited only by the accuracy of the chosen method of indication, without coming into contact with the object being surveyed. It is fully portable with provision for connection to external instruments, such as digital counters, oscilloscopes or computers, in order to provide additional dynamics data.

The heart of the Mini-Radar is a Gunn-effect diode which generates the microwave frequency of 13.4 GHz at a power output of 5mW maximum unmodulated c.w. and operates off a simple 12V nominal d.c. battery. The equipment thus costs about a third of the price of conventional apparatus with a considerable saving in space and weight.

## APPLICATIONS

The equipment has many applications as a research tool, particularly in conjunction with suitable external instrumentation, when it can be used to measure complex motions of vibration, acceleration, relative target range, distance travelled, fluid wave height and speed etc. Moreover, it is anticipated that technical and scientific educational courses will use it to demonstrate the theory and practice of Doppler effect.

The Mini-Radar can be hand held, fixed to a tripod, or suitably mounted for mobile applications. For measuring radial velocities, the function switch is turned to the appropriate speed range "10" or "100" and the target speed is indicated on a monitor meter at the rear, or on external high accuracy remote instruments if required. For rotational speeds, the function switch is turned to "RPM" and indication will be supplied by an external oscilloscope or counter; an internal loudspeaker provides useful audio indication of doppler signals within the audio frequency range and provision is made for jacking in an external audio system if required.

The range and sensitivity of the instrument depends largely on the radar cross-section area of the target. The distance involved will be only a few inches when measuring the balance wheel of a wristwatch, and may be up to 100 feet or more when viewing the impact of an armoured vehicle during parachute drop tests.

## CONSTRUCTION AND OPERATION

The Mini-Radar consists of a cast aluminium case, $4\frac{3}{4}$in x $3\frac{3}{4}$in x $2\frac{1}{4}$in, with a horn antenna projecting $3\frac{3}{16}$in, and weighs less than 40 oz.

The data recovery circuits include 16 semi-conductors of which 8 are integrated circuits, all mounted on a printed board. Indication of the target speed is shown on a moving coil meter at the rear of the casing, calibrated in units of 5 from 0-100 on a linear scale covering 1·34 inches. This meter covers two ranges which are switch selected; up to 10 m.p.h. or up to 100 m.p.h.—alternative models are calibrated in Km/h or knots. Audible indication of Doppler signals in the audio range are provided by a 2in diameter moving coil loudspeaker set in the side of the casing.

Jack sockets and sub-miniature coaxial connectors are provided where indication of the target speed is required on a remotely situated meter, tape recorder, digital counter, oscilloscope, U.V. or pen recorder, or on a computer. A further socket allows for connection to an external amplifier/loudspeaker, and the jack automatically mutes the internal speaker.

## FURTHER DATA

Two stabilisers are incorporated in the internal power supply. The electrical circuits operate on 10V and 4V; the Gunn-effect diode operates on approximately 6V at, typically, 150mA. Battery supply should be 12-14V d.c. but a mains a.c. transformer and rectifier is available.

The standard horn antenna measures $3\frac{3}{16}$in x $1\frac{3}{4}$in x $1\frac{3}{4}$in, giving a $1\frac{11}{16}$in square aperture. Beam width is 28° (3dB) in E plane, and 35° in H plane; overall gain is 15dB. Any J (ku) band antenna system may be substituted with UG419/u flange.

# TRANSISTORS AS "ADJUSTABLE ZENERS"

### by G. W. SHORT

**Planar transistors can be used instead of Zener diodes at low supply currents, and the value of the stabilised output voltage can be adjusted over a wide range. This article describes the design principles and gives an illustrative example.**

Constructors are often faced with the problem of keeping the voltage applied to a piece of equipment within safe limits. For example, a transistor battery set may have to be operated from a mains power unit whose voltage is too high and which varies with mains voltage and load variations. The standard solution to the problem is to use a Zener diode to stabilise the voltage. However, Zener diodes can still be rather expensive, and the more accurately their voltage is specified the more they cost. In cases like this, where only a moderate amount of stabilisation is needed, the approach described in this article is often an attractive alternative.

In Fig. 1 the transistor behaves very much like a Zener diode. At low values of the input voltage $V_{in}$ it passes no collector current. As $V_{in}$ is raised, a point is reached at which collector current begins to flow, and if $V_{in}$ is raised still further the collector current increases very sharply. Since this current flows through the series resistance $R_1$, which has exactly the same function here as in a Zener diode stabiliser circuit, most of the increase in $V_{in}$ is dropped across $R_1$, and the output voltage $V_{out}$ remains relatively constant.

## CIRCUIT OPERATION

In the circuit of Fig. 1, the transistor is arranged to function as a voltage-controlled device, not as a current-controlled one as occurs in most normal amplifier circuits. This means that its collector current is controlled by a voltage applied to its base rather than by a current forced into its base without regard to the base voltage. If $TR_1$ is a silicon transistor, it will pass virtually no collector current until the voltage on its base (strictly speaking, its base to emitter voltage, $V_{be}$) reaches about 0.5V. Thereafter, its collector current increases sharply; most small transistors are "fully on" and passing their maximum rated collector current when $V_{be}$ is 0·8V.

The base voltage in this circuit is determined by the setting of $R_3$. But the current through $R_3$, and therefore the voltage at its slider, depends on $V_{out}$, because it is $V_{out}$ that drives current through $R_2$ and $R_3$ in series. This means that, as $R_3$ is adjusted, the transistor begins to conduct at different values of $V_{out}$. In other words, $R_3$ is the output voltage control. When its slider is at the top of its track, stabilisation sets in at a low value of $V_{out}$. When its slider is near the bottom of the track, $V_{out}$ has to be large before enough voltage appears at the slider to bias $TR_1$ into conduction. With the slider right at the bottom, $TR_1$ never conducts. Thus by adjusting $R_3$, stabilisation can be made to begin at any voltage above

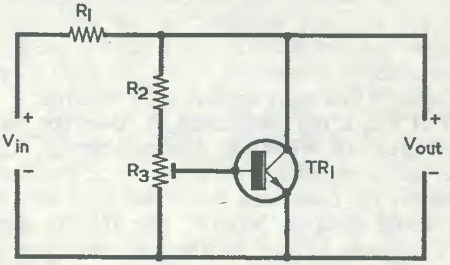


*Fig. 1. Basic stabiliser circuit. $TR_1$ behaves in much the same way as a Zener diode if the associated resistance values are correct*

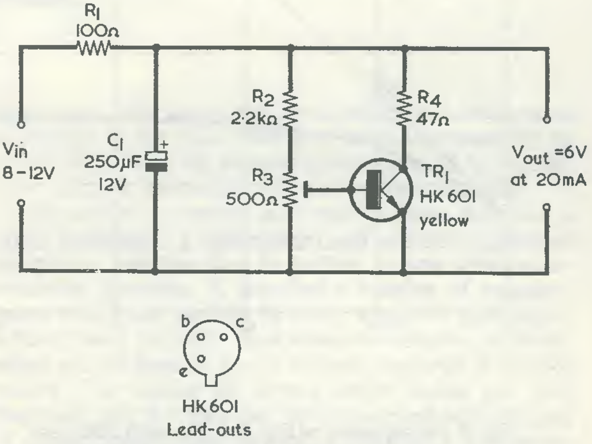


*Fig. 2. Practical stabiliser circuit*

a very low value (actually about half a volt). In practice, the maximum voltage is restricted by the collector voltage rating $V_{ceo}$ or $V_{cer}$ of the transistor.

## PRACTICAL DESIGN

As an example of what can be done with this type of circuit we shall design a stabiliser to supply a nominal 6V at 20mA from an input which varies between 8V and 12V.

The first step is to calculate $R_1$. This is done in exactly the same way as in a Zener stabiliser. The starting point is that the output voltage has to be 6V when the input voltage is at its *minimum* value of 8V and the output current is at its maximum value of 20mA. In the present case, therefore,

$$R_1 = \frac{8V - 6V}{20mA}$$

$$\doteq 100\Omega$$

In making this calculation we are ignoring the current through $R_2$ and $R_3$, which should really be added to $I_{out(max)}$. The effect will be to reduce $V_{out}$ when $V_{in}$ is minimum, but as we shall see, it is not serious provided that $TR_1$ has a high gain.

$R_1$ dissipates an appreciable amount of power when $V_{in}$ is maximum, since it must then drop 6V. The power rating of this resistor must therefore be at least:

$$\frac{V^2}{R} = \frac{6^2}{100}$$

$$= \frac{36}{100} W$$

$$= 360mW.$$

A half-watt resistor will do the job, but if the output is accidentally short-circuited it will burn out. For complete safety, it is necessary to rate $R_1$ to take the maximum possible voltage of 12V. This calls for a 1·5W rating.

We now turn to $TR_1$ and consider, first, its maximum collector current. This is the same as the maximum current in $R_1$, less the current in $R_2$ and $R_3$ and the load current. Since $R_1$, under normal operation, drops a maximum of 6V, the maximum current in it is 60mA. Ignoring the current in $R_2$ and $R_3$, this leaves 40mA collector current in $TR_1$ when the output current is 20mA. $TR_1$ must therefore be able to pass at least 40mA. Since its collector voltage is 6V, its collector dissipation must be at least 6V x 40mA, or 240mW.

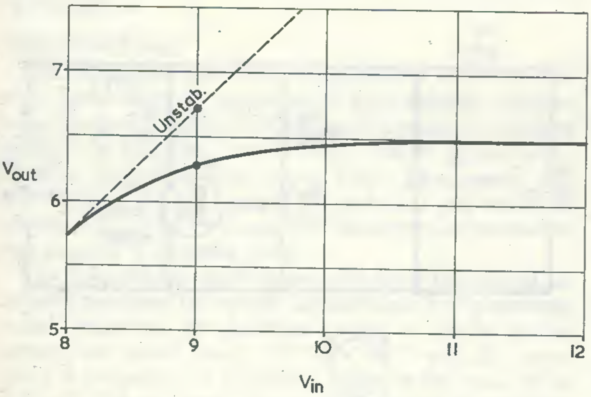


*Fig. 3. Performance of Fig. 2 circuit with 300 ohm load; i.e. 6V and 20mA. The dashed curve shows what happens when $TR_1$ is removed*

However, the possibility of the unit being switched on without any load connected ought to be allowed for. In this case $TR_1$ has to handle the full 60mA, and to dissipate 360mW. This gives us a good idea of the transistor ratings needed.

Before we can go on to work out suitable values for $R_2$ and $R_3$ we need another bit of information about $TR_1$, namely its "d.c.beta" or large-signal current amplification factor, $h_{FE}$. Plenty of high-gain transistors are available, so we shall assume that $h_{FE}$ is at least 200.

We can now calculate $R_2$ and $R_3$. The important point is that the transistor has to be voltage-controlled. This means that $R_2$ and $R_3$ must pass many times the maximum base current of $TR_1$, so as to swamp variations in base voltage which could arise from the base current, which varies from zero to $I_{c(max)}/h_{FE}$. In the present case this gives a maximum base current, in the normal working circuit, of

$$\frac{I_{c(max)}}{h_{FE}} = \frac{40mA}{200}$$

$$= 0{\cdot}2mA.$$

If the current in $R_2$ and $R_3$ is ten times this, i.e. 2mA, then

$$R_2 + R_3 = \frac{6V}{2mA}$$

$$= 3k\Omega.$$

To allow for component tolerances and transistor variations, we shall design for a maximum $V_{be}$ rather higher than we expect to need, say 1V. This fixes $R_3$ at 500Ω, so $R_2$ must be 2·5kΩ. The next lowest preferred value, 2·2kΩ will be satisfactory.

## REDUCING TRANSISTOR DISSIPATION

The component values just calculated above appear in the final circuit, Fig. 2. An example of the performance which can be obtained is shown in Fig. 3, where the dashed line illustrates what happens when the transistor is removed. The load current in Fig. 3 is approximately 20mA. The transistor shown in Fig 2 is an HK601 Yellow (available from Amatronix, Ltd., 396 Selsdon Road, South Croydon, Surrey), this being a high gain silicon type with a TO18 encapsulation.

An extra resistor, $R_4$, has suddenly appeared. Why? $R_4$ plays no part whatever in the operation of the stabiliser, but it enables the constructor to use a transistor whose collector dissipation rating (Pc max) is rather less than what at first sight appears to be required.

When $TR_1$ is not conducting, $R_4$ does not really enter the picture at all. When $TR_1$ conducts heavily, $R_4$ absorbs power which would otherwise have to be absorbed by the transistor. We calculated that if the load were removed $TR_1$ would dissipate 360mW. The HK601 specified in Fig. 2 happens to have an absolute maximum collector dissipation of 360mW, whereupon there is no margin for error. By putting $R_4$ into circuit, the collector dissipation is roughly halved without affecting the stabilising action by any measureable amount.

Choosing a value for $R_4$ is quite simple, and the value is not at all critical. All that is necessary is to ensure that, when the maximum normal collector current flows, there is still enough voltage on the collector to allow the transistor to operate properly. Most transistors work with as little as 1V on their collectors. Any value of $R_4$ which leaves, say, 2V on the collector should not, therefore, interfere with the normal operation of the stabiliser circuit. In the present instance, the maximum normal collector current is, as we have already calculated, 40mA. At this current, a resistance in $R_4$ of 50Ω would drop 2V, and the maximum collector dissipation in normal operation would be 160mW ; i.e. 4V x 40mA.

Under open-circuit load conditions, with 60mA flowing into the collector, 50Ω drops 3V and the transistor dissipation is 180mW. This is so comfortably inside the maximum rating of the transistor chosen that it is obviously possible to use the nearest standard value of 47Ω without making any more calculations. It would have been equally possible to use 56Ω, since even with 100Ω in circuit there would still be 2V left on the collector when $I_c = 40$mA. This very simple trick, which has no counterpart in Zener diode circuitry, enables the power-handling capacity of the transistor to be effectively increased.

Fig. 2 also contains an added capacitor, $C_1$. This may not be needed, because there may be one inside the equipment supplied by the stabiliser. It is absolutely necessary for $C_1$ (value, about 100 to 5,000µF, working voltage equal to $V_{in}$ max.) to be present, somewhere, if the load contains a Class B amplifier, because this will take high-current pulses which would otherwise be clipped by $R_1$. $C_1$ also helps to remove any mains ripple from the input voltage.

In Fig. 3 the output voltage falls to 5·7V for minimum input voltage, and rises to a maximum of 6·5V. As was explained earlier, the fall at the low-voltage end comes from neglecting the effect of the bleed current through $R_2$ and $R_3$. Readers should note that it is only justifiable to neglect this current if a high-gain transistor is used. If the value of $h_{FE}$ had been only 20, instead of 200, the current through $R_2$ and $R_3$ would have had to be increased to 20mA, which is equal to the load current, and hardly a practical value. The performance of the stabiliser would not, however, have suffered in proportion, because when transistors are current-controlled they do not vary much from one to another. The recipe for success with this type of stabiliser is to take one high-gain transistor, and don't worry what its exact $h_{FE}$ is, so long as it is above about 200. Two-transistor stabilisers, which work with transistors of lower gain, are possible. One obvious trick is to use a "Darlington pair" or compound transistor arrangement. But this puts up the cost, and perhaps a Zener diode is then more economical. It all depends on what you have in the spares box. ✱

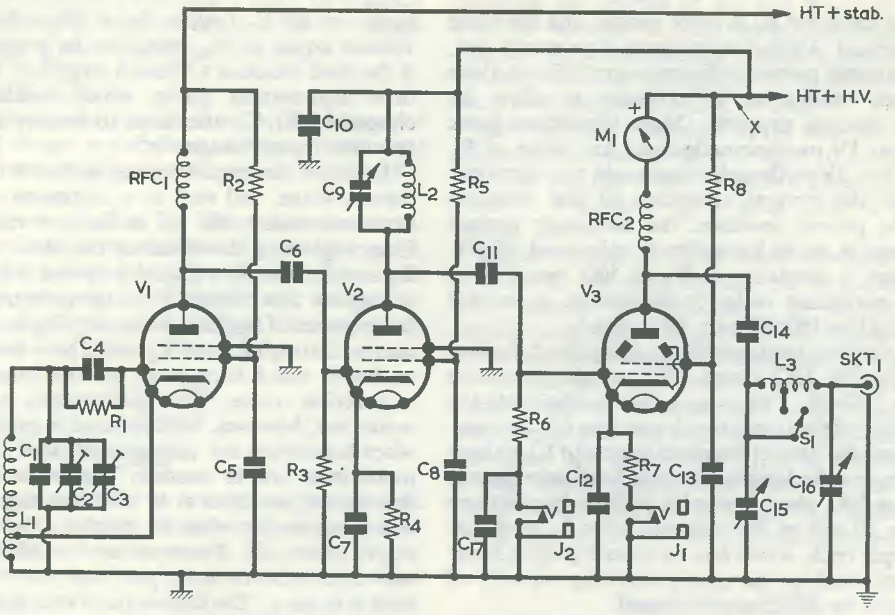
# TRANSMITTER FAULT FINDING FOR THE UNINITIATED

## by A. D. TAYLOR,

**Our contributor, an R.A.E. lecturer of ten years standing, deals with a particular aspect of transmitter work which is not covered in most R.A.E. courses.**

FOR SOME REASON THERE SEEMS TO BE A GENERAL assumption that the fact of having passed the Radio Amateurs' Examination automatically qualifies an amateur as an expert in servicing transmitters. Having had ten years experience as an R.A.E. lecturer the writer can say that this is rarely the case unless a student has had previous training in radio. About half the remaining students without such training have a modicum of practical skill, usually gained by building non-transmitting equipment, and the rest have had little or no practical experience. While some practical work is done during the average R.A.E. course, it is insufficient to make good this deficiency, particularly when one considers the breadth of the course which students with no previous radio training have to cover in one winter. All honour is due to those who pass the examination—only those who teach them know how much effort and enthusiasm is applied to the task—but it is quite unreasonable to expect the bulk of the successful candidates to be capable of servicing a transmitter without further guidance.

This article is therefore addressed to those who find a faulty transmitter a complicated and unfamiliar piece of equipment, whether they be holders of new callsigns or would-be amateurs. It describes a number of measurements which can usefully be taken when the transmitter is functioning correctly, then shows how similar measurements can be used as an aid to fault diagnosis if trouble occurs. The causes of certain other faults are also discussed. All the tests can be carried out with the aid of a multi-range testmeter and an absorption wavemeter having a simple lamp indicator or a diode rectifier and meter to indicate the r.f. amplitude across its tuned



*A basic circuit for the r.f. section of a simple transmitter operating on the 1.8 Mc/s and 3.5 Mc/s bands. Typical faults, with their diagnosis and cure, are described in the text*

circuit. Whilst the treatment may appear elementary to the experienced amateur, this article nevertheless fills a gap in current amateur literature and also a gap which is present in most R.A.E. courses because of the amount of ground which has to be covered in the time available for lectures and demonstrations.

## TYPICAL TRANSMITTER CIRCUIT

A large number of newly licensed amateurs start off with a simple transmitter covering the two lowest frequency amateur bands. The accompanying diagram shows a typical basic circuit for the r.f. portion of such a transmitter. $V_1$ is an electron coupled oscillator operating in the 1·8 Mc/s band, $V_2$ is a buffer/doubler providing output on either 1·8 or 3·5 Mc/s and $V_3$ is a power amplifier which can also be tuned to either of these bands. H.T. for the oscillator is derived from a stabilised supply and a common unstabilised supply of higher voltage is used for the other two stages.

Only one meter, $M_1$, is provided, this being connected so that it reads the p.a. anode current. The transmitter can be keyed in the p.a. stage cathode circuit via $J_1$, the key click filter being located externally. If plate and screen-grid modulation is required, the h.t. line to the p.a. can be broken at the point marked X in the diagram.

## FIGURES WHICH CAN BE RECORDED

One of the most useful aids to fault finding is a set of nominal figures of current and voltage taken when the equipment is functioning correctly. Provided a multi-range meter having a minimum internal resistance of 1000Ω per volt on the voltage ranges is available it is comparatively easy to take the necessary measurements. They should be made when the transmitter is correctly tuned and loaded, and a list of suitable measurements is given in the Table.

A further useful reading is the grid current of $V_2$. To take this, the earthy end of $R_3$ must be disconnected from the chassis and a mica capacitor (any value between 1000pF and 0·01μF) connected between the free end of this resistor and chassis. If a milliameter is then connected across the capacitor the grid current can be measured.

It must be realised that as the unstabilised supply voltages are derived from a mains operated power pack they will vary if the local mains supply voltage rises or falls. This often happens, particularly in heavily populated areas, so variations of up to 10% between readings taken at different times may be ignored. Larger variations should be investigated, however. In particular, a steady decrease in h.t. voltage over a period indicates either a loss of emission in the h.t. rectifier valve or an

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### TABLE

Suggested reference measurements, to be taken and recorded with the transmitter correctly tuned up and loaded.

**Voltage**

V.F.O. h.t. positive line to chassis.
V.F.O. valve screen-grid pin to chassis.
Buffer/p.a. h.t. positive line to chassis.
$V_2$ screen-grid pin to chassis.
$V_3$ screen-grid pin to chassis.
Voltage across $R_4$.

**Current**

Reading in meter $M_1$ (p.a. anode current).
Reading in a meter jacked into $J_1$ (p.a. cathode current).
Reading in a meter jacked into $J_2$ (p.a. grid current).

*(continued on page 503)*

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# RADIO CONSTRUCTORS DATA SHEET

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# SOUND FREQUENCY-WAVELENGTH TABLE

The velocity of sound in air at 20°C is approximately 1,130 ft per second, or 344 metres per second. Wavelength is sound velocity divided by frequency, and the Table gives calculated wavelength figures for frequencies from 10 c/s to 100 kc/s.

| Frequency (c/s) | Wavelength | | Frequency (kc/s) | Wavelength | |
|---|---|---|---|---|---|
| | ft | metres | | in | cm |
| 10 | 113 | 34·4 | 1 | 13·6 | 34·4 |
| 15 | 75·3 | 23·0 | 1·5 | 9·04 | 23·0 |
| 20 | 56·5 | 17·2 | 2 | 6·78 | 17·2 |
| 30 | 37·7 | 11·5 | 3 | 4·52 | 11·5 |
| 40 | 28·2 | 8·61 | 4 | 3·39 | 8·61 |
| 50 | 22·6 | 6·89 | 5 | 2·71 | 6·89 |
| 60 | 18·8 | 5·74 | 6 | 2·26 | 5·74 |
| 70 | 16·1 | 4·92 | 7 | 1·94 | 4·92 |
| 80 | 14·1 | 4·30 | 8 | 1·70 | 4·30 |
| 90 | 12·6 | 3·83 | 9 | 1·51 | 3·83 |
| 100 | 11·3 | 3·44 | 10 | 1·36 | 3·44 |
| 150 | 7·53 | 2·30 | 15 | 0·904 | 2·30 |
| 200 | 5·65 | 1·72 | 20 | 0·678 | 1·72 |
| 300 | 3·77 | 1·15 | 30 | 0·452 | 1·15 |
| 400 | 2·82 | 0·861 | 40 | 0·339 | 0·861 |
| 500 | 2·26 | 0·689 | 50 | 0·271 | 0·689 |
| 600 | 1·88 | 0·574 | 60 | 0·226 | 0·574 |
| 700 | 1·61 | 0·492 | 70 | 0·194 | 0·492 |
| 800 | 1·41 | 0·430 | 80 | 0·170 | 0·430 |
| 900 | 1·26 | 0·383 | 90 | 0·151 | 0·383 |
| 1,000 | 1·13 | 0·344 | 100 | 0·136 | 0·344 |

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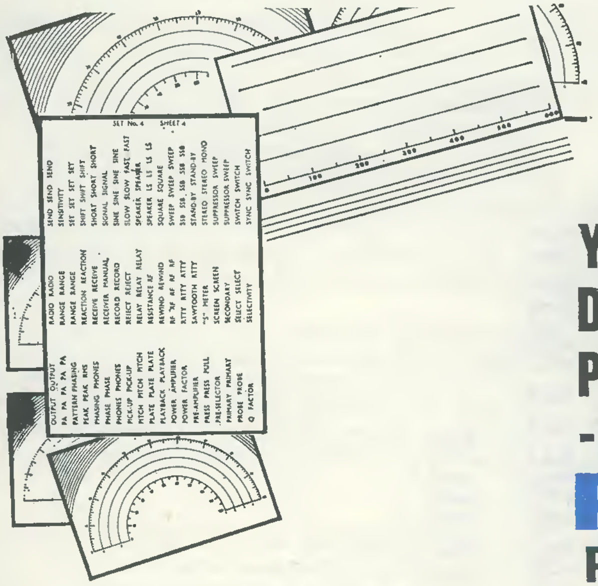

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## TRANSMITTER FAULT-FINDING FOR THE UNINITIATED

*(continued from page 500)*

increased leakage current in one or more of the smoothing capacitors, and it should be investigated.

Similarly, a steady, long term decrease in the current drawn by a given valve in the transmitter indicates a gradual loss of emission and the valve should be replaced before this has gone too far.

### P.A. AND DOUBLER FAULT ANALYSIS

Fault analysis in the p.a. and buffer/doubler stages may be carried out with the aid of current and voltage measurements. It is convenient to cover this subject by considering each type of common fault in turn and explaining how it can be analysed by making the appropriate measurements. In each instance an attempt is made to give an exhaustive analysis so that every likely cause of the fault is covered. Obviously, the power supplies are switched off when making resistance and continuity checks with the meter switched to ohms.

*Fault No.* 1. $V_1$ and $V_2$ are operating normally, but when the key is pressed meter $M_1$ indicates that $V_3$ is only drawing two or three milliamps of anode current. This fault indicates either a screen-grid voltage failure or a very high resistance in the cathode circuit. Assuming that jack $J_1$ is of the self-shorting type, pull out the key jack. If the anode current is immediately restored to its original value the fault is in the external keying circuit and this must be checked to find the high resistance joint or component. If the anode current remains the same, check the voltage between the screen-grid pin of $V_3$ and chassis. If this voltage is very low or non-existent, disconnect the screen-grid decoupling capacitor, $C_{13}$, from chassis and repeat the voltage measurement. If the voltage is now correct, $C_{13}$ is partially or wholly broken down. If the voltage is still low or non-existent $R_8$ is faulty. If the screen-grid voltage is found to be between its normal value and that of the h.t. positive line the fault must lie either in the cathode bias resistor, $R_7$, or the wiring associated with jack $J_1$. The value of $R_7$ must be checked, using the meter on an ohms range, and if it is correct the continuity of the cathode circuit wiring and $J_1$ must be checked until the bad joint is located and rectified.

*Fault No.* 2. $V_1$ and $V_2$ are operating normally but $V_3$ draws no current whatsoever when the key is pressed. This fault can be due to a number of causes which will become apparent as the method of investigating it is described. First withdraw the key jack from $J_1$. If the valve draws normal current there is a break in the external keying circuit and this must be located and repaired. If the valve still draws no current, check that the normal voltage appears between the anode pin and chassis. If it does not, check the continuity of the circuit from the h.t. positive line through meter $M_1$ and $RFC_2$ to the anode pin. When the break is located, repair it. If the correct voltage is present at the anode, check the screen-grid voltage, using the method described under Fault No. 1. If the screen-grid voltage is correct, check $R_7$ with an ohmmeter. If this resistor is functioning correctly, check that the correct voltage is present at the heater pins of $V_3$. If it is not, find the discontinuity in the associated circuit and correct it. If the correct heater voltage is present, unplug $V_3$ and check its heater for continuity. If the heater is open-circuit replace the valve. If the heater is intact the only likely causes of the fault which remain are either a poor contact between one or more of the valve pins and the valveholder or a faulty connection within the valve itself. The valve pins should be carefully cleaned and lightly smeared with switch cleaning fluid. A small amount of the cleaning fluid should also be dropped into each of the contact holes on the valveholder. If this does not clear the trouble the valve should be replaced.

*Fault No.* 3. $V_1$ and $V_2$ are functioning correctly, but $V_3$ takes full current even when $C_{15}$ is tuned through its normal resonance setting. (It is assumed that the correct settings of $C_{15}$ and $C_{16}$ are known and that $C_{16}$ has been set to the right value.) Jack a meter into $J_2$ and see if the correct grid current is flowing. If it is not, use the absorption wavemeter, coupled to $L_2$, to check that $V_2$ is delivering r.f. at the correct frequency. If the r.f. is present, either $C_{11}$ or $R_6$ is open-circuit. $R_6$ should be checked with the ohmmeter. If it is faulty it should be replaced, and if it is showing the correct resistance $C_{11}$ should be replaced. If grid current is found to be present at the grid of $V_3$, the fault must lie in the output circuit of the valve. The whole circuit between the anode of $V_3$ and $SKT_1$ should be checked for continuity. If a break is found it should be repaired. If there is no break in the circuit, $C_{15}$ and $C_{16}$ should be checked to see if a short-circuit has developed on either of them. If it has it should be corrected, but if the capacitors are functioning correctly $C_{14}$ should be replaced, as it is likely to be open circuit.

Almost identical methods to those described above can be used for servicing the buffer stage. No anode current meter is provided for this stage, but similar results can be obtained by connecting a voltmeter across the cathode bias resistor, $R_4$. The voltage across this resistor is equal to I multiplied by R, where I is the cathode current and R the resistance of $R_4$. As a result, when $C_9$ is tuned through resonance and the current through $V_2$ drops, the voltage drop across the resistor will also decrease, thus allowing the voltmeter to be used as a resonance indicator in the same way as meter $M_1$. As already stated, grid current can be measured by disconnecting $R_3$ from chassis and using a meter and bypass capacitor.

### V.F.O. FAULTS

We turn next to the v.f.o. stage, where we shall consider four basic faults and their diagnosis.

*Fault No.* 1. The oscillator does not function. Carry out the anode, screen-grid and heater voltage tests described earlier. If these voltages are correct, check the continuity of all the wiring associated with the grid circuit, including the coil and the cathode tap. If the circuit still does not oscillate, check capacitors $C_1$, $C_2$ and $C_3$ for short-circuit. If these capacitors are functioning correctly, clean the valve pins and valveholder contacts using the method already described. If this does not clear the fault, change the valve.

*Fault No.* 2. The oscillator frequency changes suddenly, and by a small amount, at random intervals of time. Changes of this type are almost always caused by variations in contact resistance somewhere in the v.f.o.

circuit, and the most likely cause is a poor contact at the valve base. It is often possible to verify this by gently pushing the valve backwards and forwards with the end of a wooden ruler and seeing whether the symptoms are reproduced. Whether this test is carried out or not, the first remedial action should be to check and clean the valve pins and the valveholder contacts. If this does not clear the fault, every soldered joint in the v.f.o. circuit should be checked. This can be done by using an insulated hook to pull every connecting lead in turn at the point or points where it is soldered. A plastic crochet hook is a suitable tool for this operation. At the same time any solder tags which are bolted to the chassis should be unbolted and the tag itself and the area of the chassis with which it makes contact should be carefully cleaned. When replacing the tag it should be bolted down really tight. The moving vanes of $C_2$ and $C_3$ should also be checked to ensure that there is no possibility of an intermittent contact in their earth return circuits.

During these operations the opportunity should be taken to check that no components are free to move about and that all tagstrips and chassis-mounted components are firmly bolted down. The mechanical and electrical stability of the v.f.o. screening box must also be checked. The box should be firmly bolted to the chassis in such a way that a good electrical connection is provided, and similar precautions must be taken when bolting on the lid of the box. If these checks do not cure the instability, change the valve, and if this does not cure the trouble change firstly $R_2$ and then $R_1$. If the fault is still present the remaining likely causes are either a poor internal contact in $C_1$ or $C_4$, or a partial fracture in the coil winding, probably caused by the wire being kinked before it was drawn tight. The capacitors should be changed first, and the coil as a last resort.

*Fault No*. 3. After the v.f.o. has been switched on for a while the note suddenly becomes rough and exhibits an a.c. ripple. It may be possible to temporarily clear the fault by switching off for a period then switching on again. This fault is caused by defective heater-cathode insulation in $V_1$. The only cure is to change the valve.

*Fault No*. 4. The transmitter aerial system is changed and the note immediately becomes rough. When modulation is applied to the transmitter there are symptoms of r.f. feedback in the modulator. In this instance the fault does not lie in the v.f.o. itself. If a short aerial and/or a long, rather high resistance earth lead is used, the transmitter chassis often tends to "float" at an r.f. potential, thus causing r.f. feedback. Cures are as follows. If possible, shorten the earth lead, improve the efficiency of the earth connection itself and lengthen the aerial, say by running more wire down the mast. If it is not possible to do this an alternative solution is to get the r.f. out of the shack by locating the aerial tuning unit at the remote end of the aerial and making the earth connection at this point. The transmitter can be connected to the a.t.u. via a suitable length of coaxial cable.

## MODULATOR FAULTS

All the techniques of voltage, current and continuity testing already mentioned can be used when servicing a modulator, which is after all only an audio amplifier. As this article is basically written to cover the servicing of the r.f. stages of a transmitter, only two possible modulator troubles will be discussed.

The first of these is the possibility of feedback caused by r.f. picked up on the microphone leads. This can be avoided by using a reasonably short, well-screened lead and ensuring that a really good job of bonding is done at the microphone case and the co-axial plug on which the lead is terminated. Careful earthing of the modulator chassis itself is also important. Equally damaging pick-up can take place in the grid circuit of the first speech amplifier valve, so it is essential not to alter any screening arrangements that the designer may have incorporated.

A second fairly common modulation "fault", which the writer has seen even professional communication engineers baffled by, sometimes occurs in transmitters using a common power supply for the modulator and p.a. valves. The matching between the modulator and the p.a. is correct and there is adequate drive to the p.a. grid, but "downward modulation" occurs and no amount of readjustment will cure it. The cause is simple. The h.t. supply is being overloaded on modulation peaks, causing the h.t. voltage applied to the p.a. anode to drop sharply, and this in turn causes the reading in the anode current and aerial meters to drop. The cure is to use separate power supplies for the two stages.

## CONCLUSION

It is obviously impossible to cover every sort of transmitter fault in an article of this length, but it is hoped that the information provided will give those not previously familiar with the subject the confidence necessary to tackle faults which may occur on their own equipment.

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## CONFERENCE—RELIABILITY IN ELECTRONICS

The reliability of electronic equipment will form the subject of a conference to be held at Savoy Place, London WC2 from the 10th to 12th December, 1969. The conference is being organised by the IEE in association with the Institute of Physics and the Physical Society, the Institution of Electronic and Radio Engineers and the Institute of Electrical and Electronic Engineers (UK & Republic of Ireland Section). The emphasis of the conference will be on the practical, rather than the theoretical aspects of the subject, i.e., on how realistic reliability programmes can be achieved. It is hoped to assess the state of the art, to promote discussion between manufacturers and users, and to relate the physics of reliability to the hard facts of failure rates.

The scope of the conference will include the design requirements for reliability and assessment procedures, as well as the study of causes of failure and the analysis of case histories.

The conference organising committee invite offers of contributions and intending authors should submit a 200 word synopsis to the IEE Conference Department by the 1st April, 1969.

Further details of the conference and registration forms will be available in due course from the Conference Department, IEE, Savoy Place, London WC2.

# SOLID-STATE AUDIO GENERATOR

## PART 2

by

**G. A. STANTON, G3SCV**

**In last month's issue, full details were given for the circuit operation of this high-performance design. The present article concludes the 2-part series, and deals with construction, setting up and calibration.**

### CONSTRUCTION

Construction of the instrument is straightforward, almost all the components being mounted on four printed circuit boards, details of which are given in Fig. 3. No attempt has been made at miniaturisation and standard components are used throughout. It will be obvious that only first class components can give dependable results, and these should be fixed in place as firmly as possible. This applies especially to the oscillator sections.

The printed circuit board for panel A is illustrated in Fig. 3 (a) and here, as in the remaining drawings of Fig. 3, the view is such that the copper side is towards the reader with all the components on the other side of the board. Coil $L_2$ is mounted vertically with coil tags away from the board, these being connected by insulated wires to the circuit points indicated. Coil $L_1$ has its pins connected directly into the printed circuit, as shown. Trimmer $VC_3$ in the prototype is of the type which has a rotating silvered ceramic disc coupled directly to the adjusting screw. Mounting holes should be made to suit the particular trimmer employed.

Panel B appears in Fig. 3 (b), and the remarks for $L_1$ and $VC_3$ of Panel A apply similarly to $L_3$ and $VC_6$ respectively.

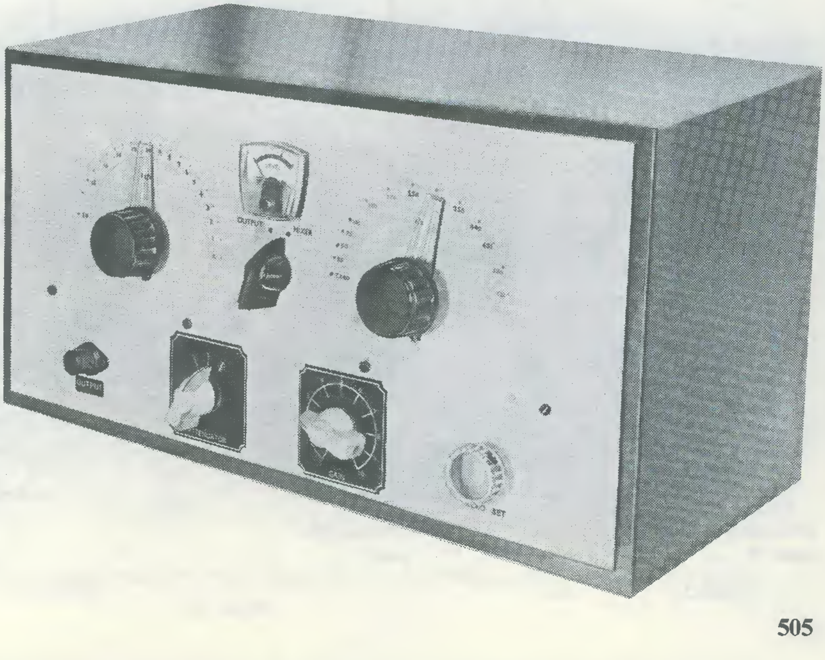
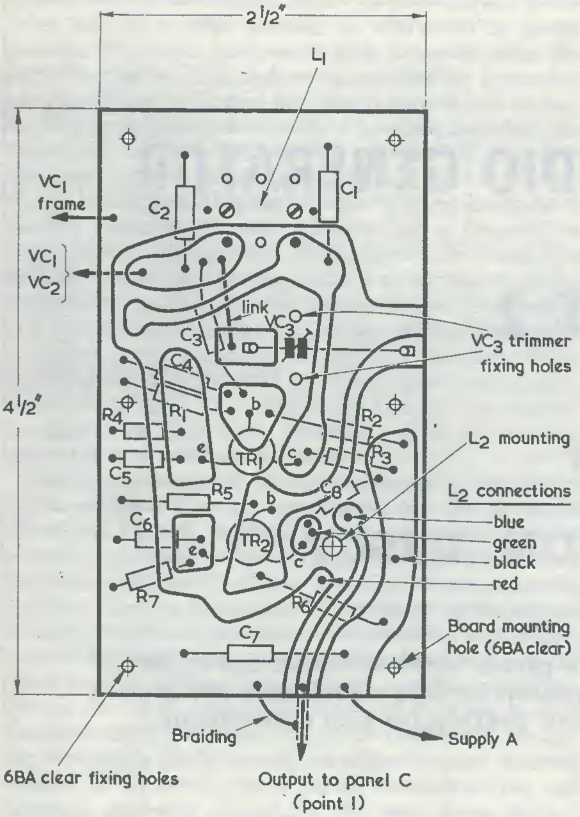
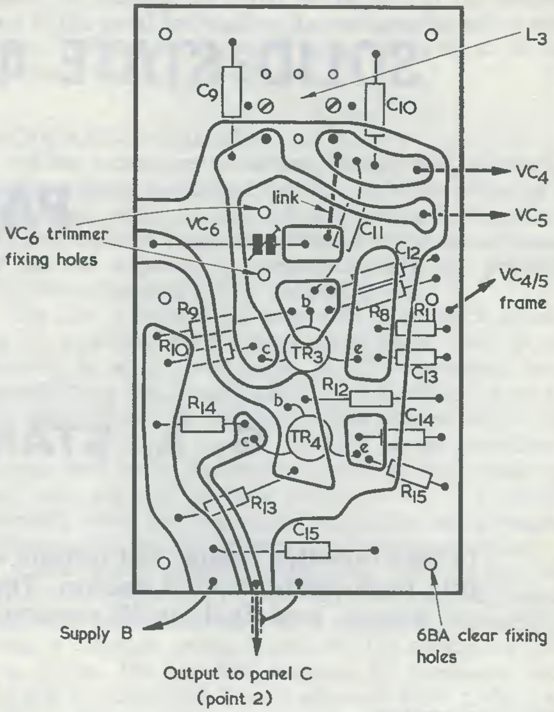


Fig. 3 (c) shows panel C. Trimmer $VC_7$ is of the same type as $VC_3$ and $VC_6$ and the same comments apply here once more. The pot core assembly ($L_4$) is mounted "upside down" by means of the nylon screw provided (or by means of a suitable adhesive if no screw is available). This enables the core to be adjusted from above if necessary.

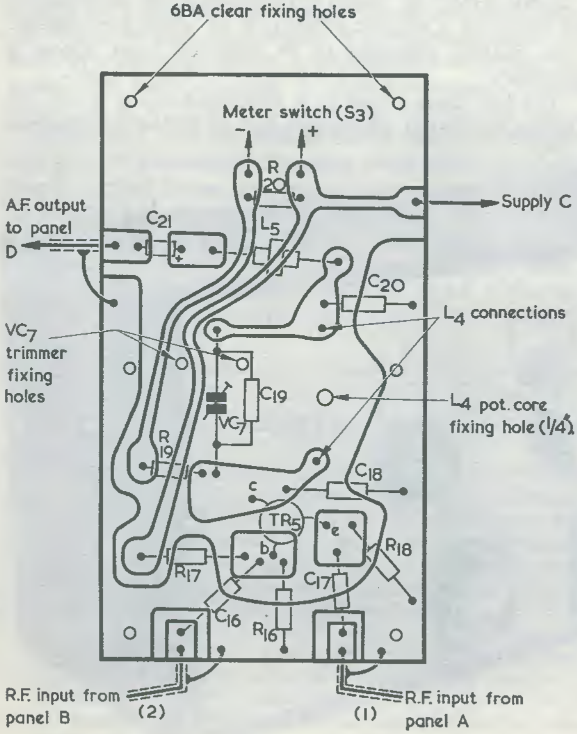
The last panel, panel D, is illustrated in Fig. 3 (d). No further comments are needed here as all the components



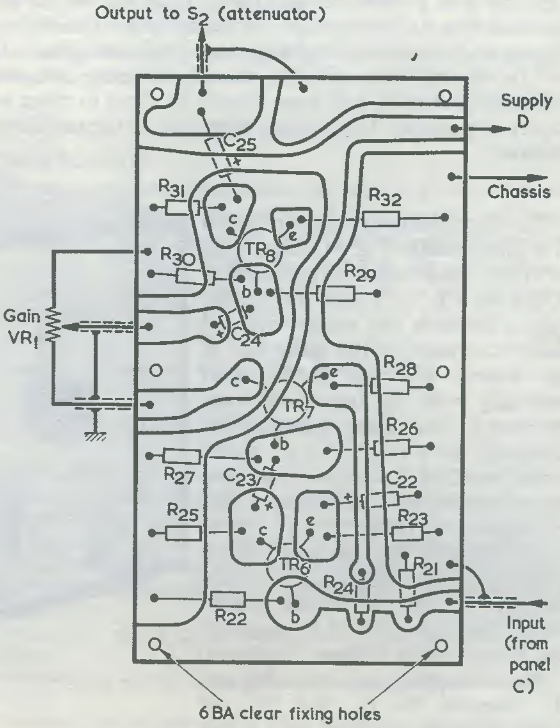
PANEL A (a)



PANEL B (b)



PANEL C (c)



PANEL D (d)

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*Fig. 3 (a). The printed circuit board for panel A. The copper is towards the reader, and the components are on the other side of the board*
*(b). Layout for Panel B*
*(c). The mixer connections and components for panel C*
*(d). Panel D, the fourth printed circuit board*

on this panel are resistors, capacitors and transistors, which are mounted in normal manner.

All the panels measure $2\frac{1}{2}$ by $4\frac{1}{2}$in, and have six 6BA clear mounting holes.

The panels are spaced off from the surface to which they are mounted by means of spacing washers (see Figs. 5 (c) and (d)). Sections of the copper pattern adjacent to the mounting holes, and which are not at chassis potential, must be dimensioned such that they will not short-circuit to the spacing washers.

(The four panels of Fig. 3 are reproduced on a reduced scale, as the diagrams would take up too great a space if reproduced full size for tracing. With the present design, the copper layout dimensions are not critical provided that care is taken to correctly locate the pin and mounting holes of $L_1$ and $L_3$.—Editor.)

## COIL WINDING AND METALWORK

As was mentioned last month, coil $L_4$ consists of a pot core assembly. It has 296 turns of 40 s.w.g. enamelled wire wound on a Neosid pot core type 10D.

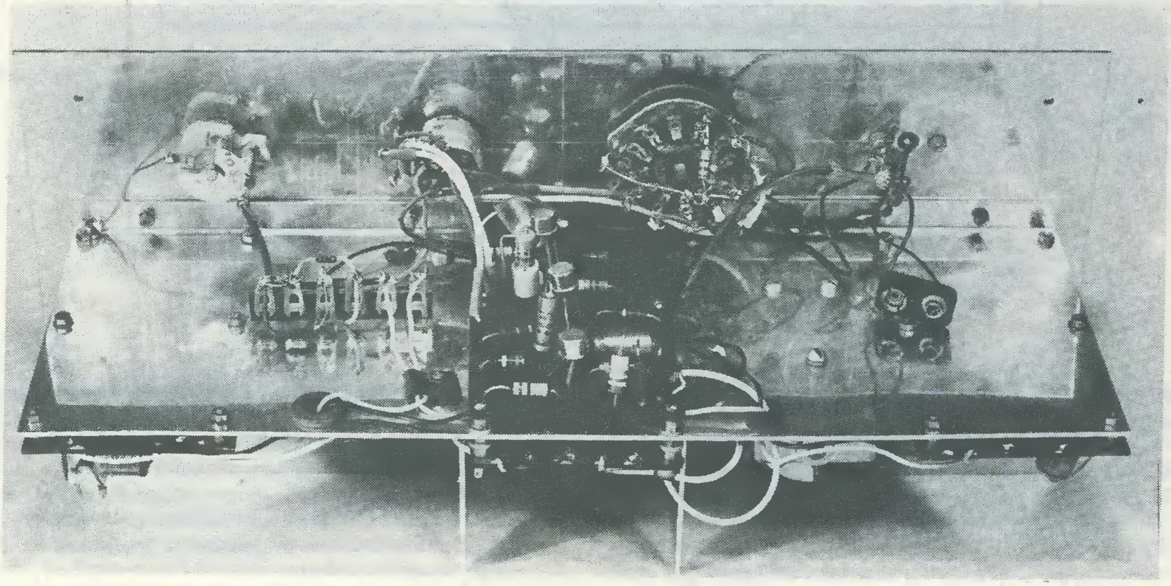
The metalwork of the instrument consists of a panel-shelf arrangement with extra rigidity imparted by two screens which are bolted to both the panel and the shelf. Details are given in Fig. 4 (a) and the subsequent diagrams, and these also indicate the general layout. Exact measurements will depend upon the larger components used including, in particular, the meter, the two tuning capacitors $VC_1$ and $VC_4/VC_5$, and the dial drives. (Dial drive centres are at the required height for a Jackson Bros. type L capacitor in the $VC_4/VC_5$ position.) If expense is no object professional dials can be used, but the author has found epicyclic drives and Data Panel-Sign Transfer scales quite satisfactory. Constructors should first obtain the larger components and confirm that they will fit into the dimensions given. If not, the appropriate changes can be made before the metalwork is cut out. In general, however, the dimensions given here should be suitable with nearly all standard parts.

Fig. 4 (a) shows the front panel layout, and Fig. 4 (b) a view behind the panel with controls identified. Views from above and below appear in Figs. 4 (c) and (d) respectively. Note the screens on either side of panel C.

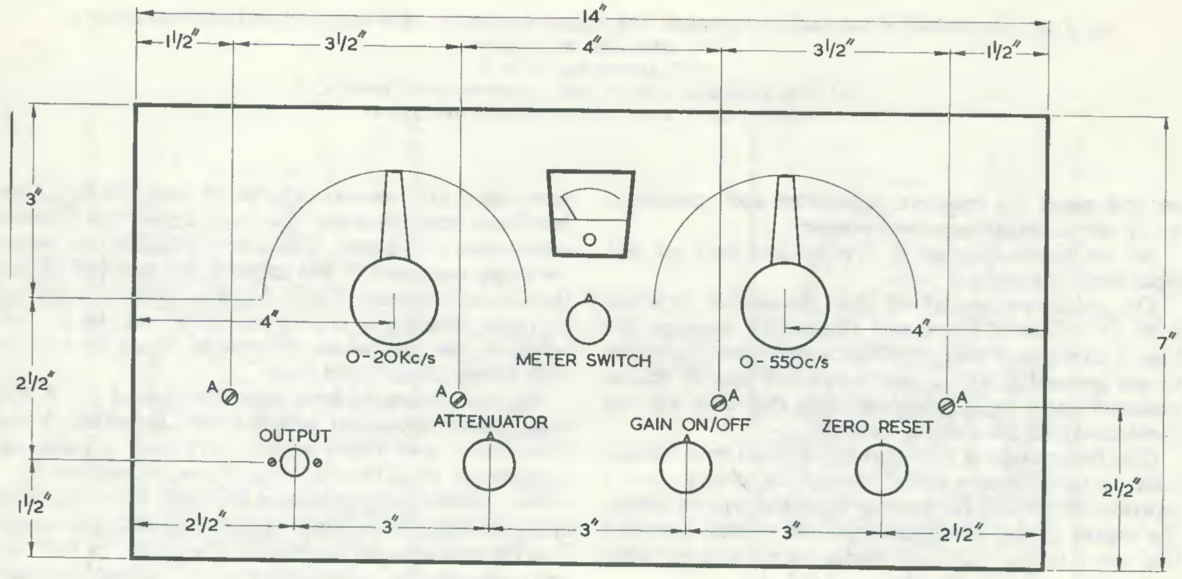
Both the variable capacitors $VC_1$ and $VC_4/VC_5$ have epicyclic drives with flanges capable of taking a cursor. Spacing washers may be fitted to the mounting bolts for one or the other of these capacitors, as required, to ensure that their spindles are the same height above the shelf. If $VC_1$ is a panel-mounting capacitor instead of the chassis-mounting type specified, an additional metal bracket will need to be made up and secured to the shelf. $VC_1$ bush will then be mounted at a hole in this bracket.

Fig. 5 (a) shows the manner in which the shelf is attached to the front panel, whilst Fig. 5 (b) illustrates the screen dimensions after bending. In both diagrams, the material is 16 s.w.g. aluminium sheet. Both right and left hand screens appear in Fig. 5 (b). With each screen, the $\frac{1}{2}$in flange along the 4in edge bolts to the shelf whilst the $\frac{1}{2}$in flange along the $2\frac{1}{2}$in edge (bent the opposite way) bolts to the panel.

Fig. 5 (c) shows how the panels A and B are secured to the shelf with spacing washers. Panels C and D appear on either side of the shelf (see Fig. 5 (d)) and share the same

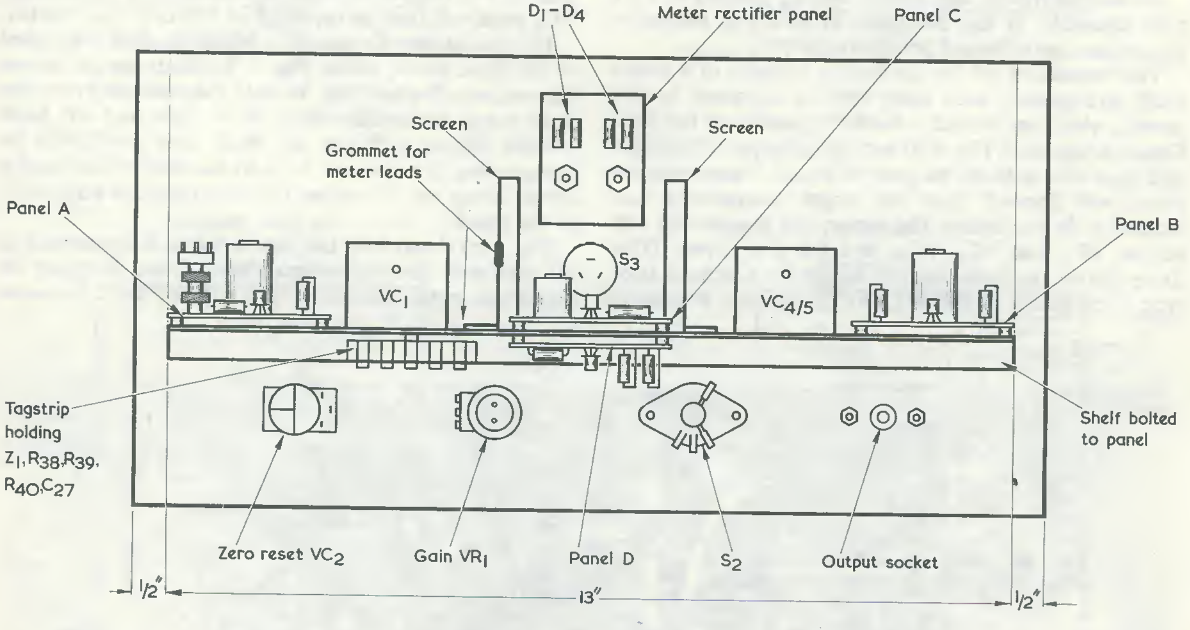


*Under the chassis of the Beat Frequency Signal Generator. Panel D is in the centre, with the battery connector to its left*



N.B. A – 6BA bolts securing shelf to panel

(a)



(b)

six mounting bolts. When drilling the fixing holes in panels C and D, mounting to the shelf later will be facilitated if the panels are clamped together with the copper sides together to ensure that the holes exactly correspond.

The attenuator components are mounted directly onto the tags of the attenuator switch, $S_2$. Those associated with the meter are mounted on a small piece of circuit board held in place by the meter terminals. The zener diode, the resistors connected with it, and $C_{27}$, are wired to a 5-way tagstrip.

The whole instrument is conveniently housed in a simple box made from $\frac{3}{8}$in plywood.

## ALIGNMENT

Before the instrument can be calibrated a number of preliminary adjustments are necessary, the first of which is to align the two oscillators. To do this an oscilloscope is connected to the output of the instrument; $VC_3$ and $VC_6$ are set at minimum capacitance, the two tuning capacitors ($VC_1$ and $VC_4/VC_5$) are set at maximum capacitance

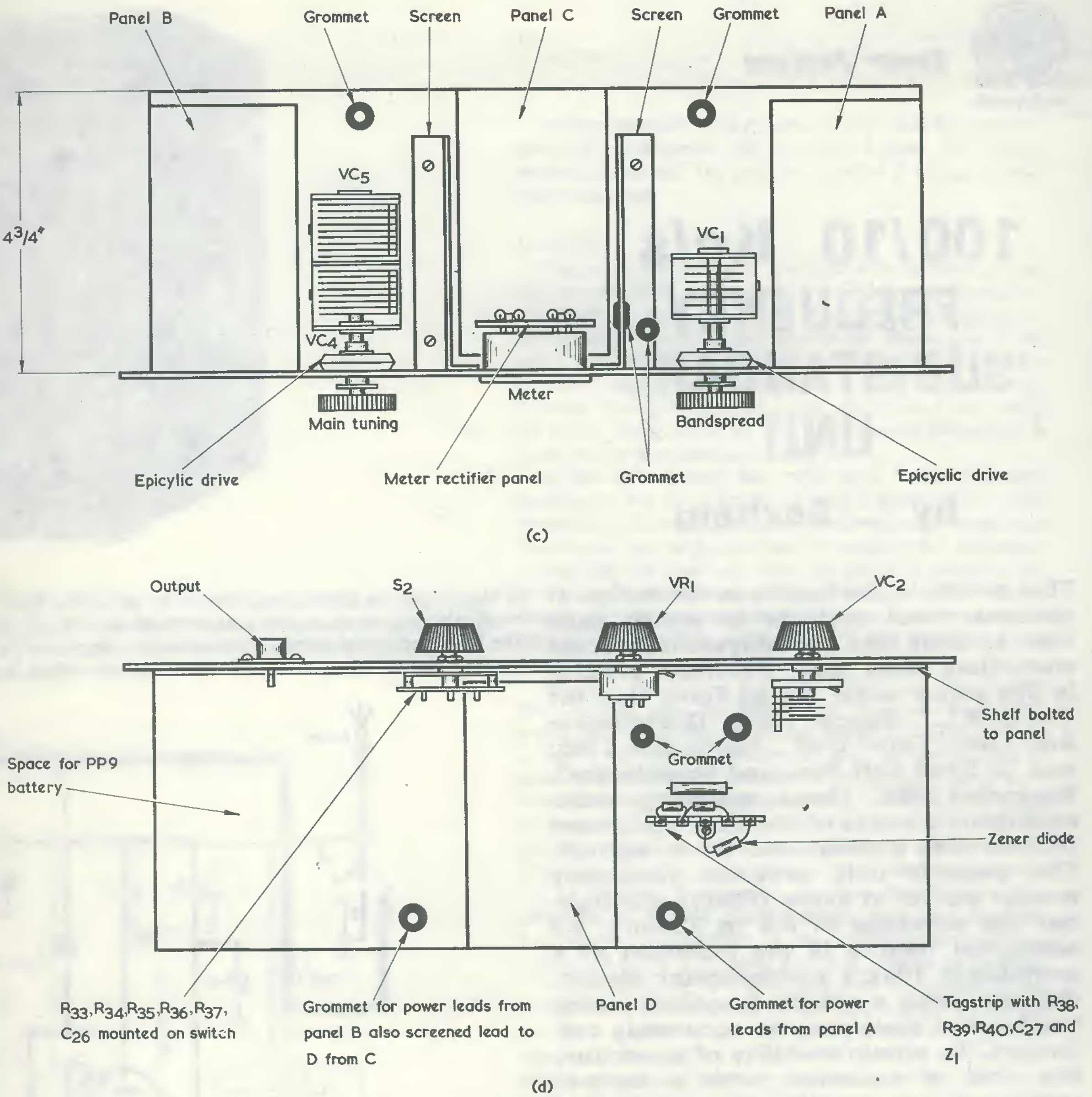


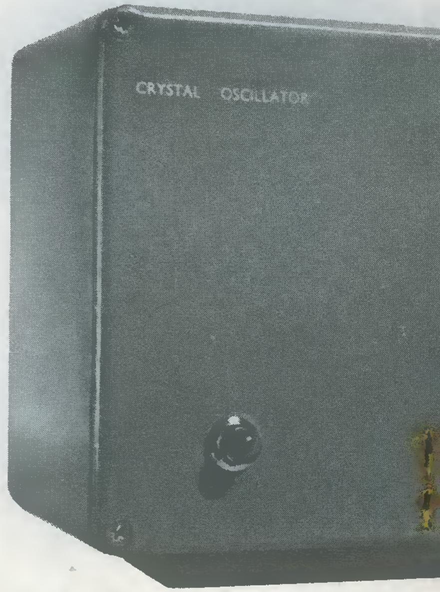
*Fig. 4(a). The front panel with the dimensions employed in the prototype*
*(b). View from the rear, illustrating the positions of the major components and assemblies*
*(c). Above-chassis view, showing grommet positions and further layout details*
*(d). Panel D and the other under-chassis assemblies take up the positions shown here*

and the zero control ($VC_2$) at its mid point. $L_3$ is adjusted until the top of the core is approximately $\frac{3}{4}$in below the top of its screening can. With both gain and attenuator controls set for maximum output, a display will be visible on the oscilloscope screen and $L_1$ is carefully adjusted until zero beat is indicated. In the prototype the core of $L_1$ is $\frac{3}{8}$in below the screening can, but the exact position will be determined by component tolerances. With $VC_1$ re-set to its mid point position, the core of $L_2$ is tuned for maximum response. This completes the alignment procedure.

In order to adjust the filter circuit, the output from the variable frequency oscillator is short-circuited by clipping a 0·1μF capacitor from the base of $TR_5$ to chassis. The oscilloscope will then display an amount of r.f. $VC_7$ is next adjusted for minimum response and a definite null point should be observed, this being the correct setting. With the 0·1μF capacitor removed it only remains to adjust $VC_3$ and $VC_6$ for maximum undistorted output, and a good sine wave should be obtainable over the whole audio range.

*(continued on page 521)*

Cover Feature

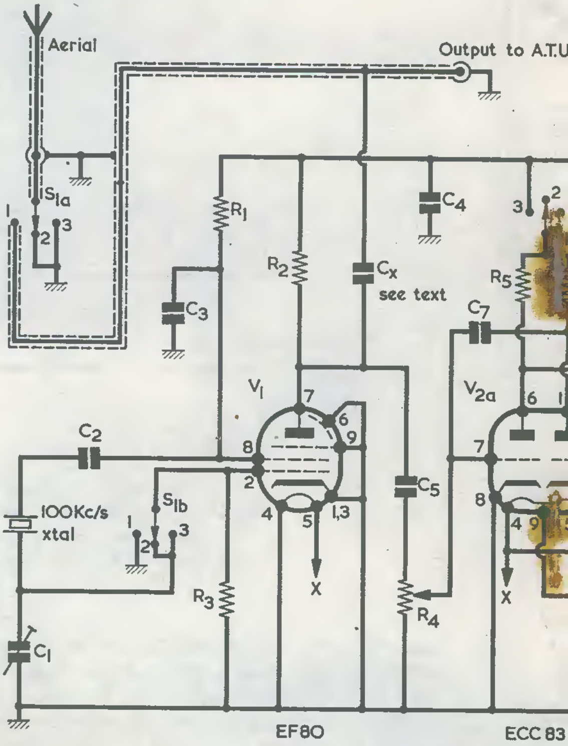


# 100/10 Kc/s FREQUENCY SUB-STANDARD UNIT

### by L. Saxham

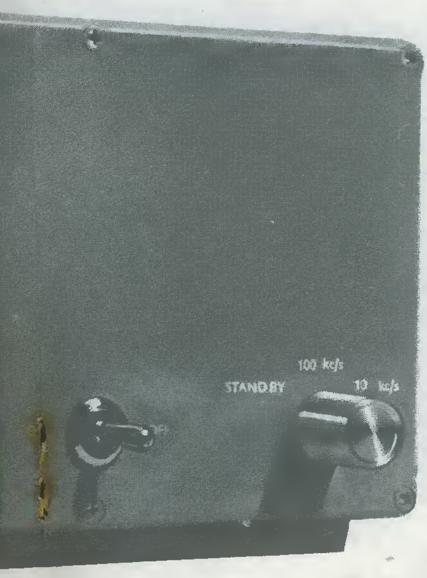
**This article is the fourth in the series of constructional projects in which each item is built into an Eddystone Diecast aluminium alloy Box. Previous articles in this series were: "Aerial Tuner Unit for The S.W.L.", August 1968; "Q Multiplier And Audio Filter Unit", September 1968; and "3-Band Self-Powered Preselector", December 1968. These matching units constitute a series of ancillary equipment for use with a communications receiver. The present unit provides frequency marker points at every 100kc/s throughout the coverage of 0·5 to 32Mc/s. An additional feature is the inclusion of a switchable 10kc/s multivibrator circuit, this providing a standard against which bandspread dials may be accurately calibrated. To obtain stability of operation, the unit is operated with a built-in stabilised h.t. supply, the box being provided with adequate ventilation.**

An accurate and stable frequency sub-standard unit is a virtual necessity when operating a communications receiver over the short wave bands. This is particularly true when serious short wave listening is the eventual aim of the operator. With the aid of this unit, the receiver bandset dial readings may be accurately calibrated throughout the frequency range. Using the 100 kc/s oscillator and lining up the Mc/s dial markings both with the dial cursor and the marker point, the dial will then exhibit a true frequency reading. With this dial set to a band edge or a megacycle reading—say 5 Mc/s—and the bandspread dial set to zero, the 10 kc/s multivibrator circuit may be next switched into operation, the bandspread dial rotated throughout its range and the marker points obtained read off, thus providing an

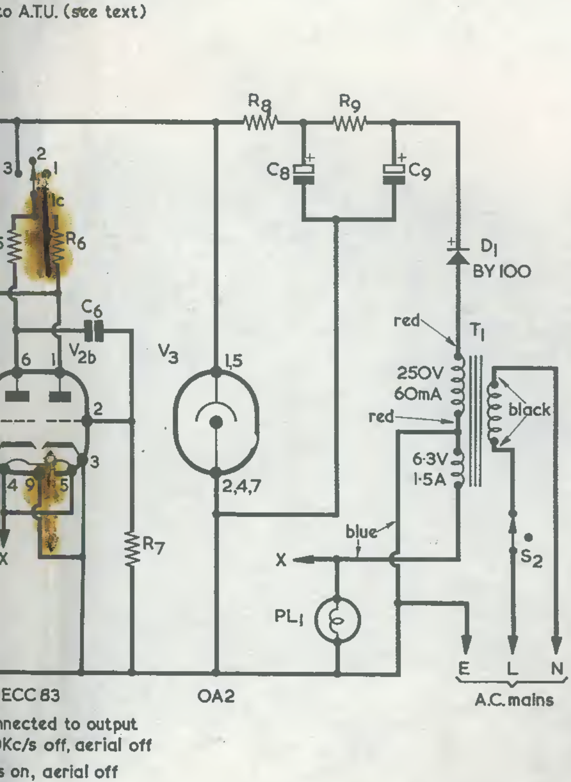


S1a 1b 1c Position 1 Osc. off, aerial connected
" 2 100Kc/s osc. on, 10Kc/s of
" 3 10Kc/s on, 100Kc/s on, ae

Fig. 1. The circuit of the Frequency Sub-Standard. $V_1$ is
and $V_3$ the voltag



accurate indication of the frequencies over which this latter dial is operating. This process can be carried out for all broadcast and amateur bands within the frequency range of the receiver.



. $V_1$ *is the 100kc/s oscillator,* $V_2$ *the 10kc/s multivibrator voltage stabiliser.*

During the calibrating process, a graph may be prepared showing bandspread dial readings against the 10kc/s marker points and the method adopted is discussed in a later paragraph.

## CIRCUIT

This is shown in Fig. 1. The 100 kc/s oscillator stage, $V_1$, uses an EF80 r.f. pentode in a Colpitts configuration, the feedback being produced by capacitive coupling via the crystal from the signal grid to the screen grid of the valve. This circuit, when correctly adjusted, will provide a sure-fire fundamental oscillation at 100 kc/s and extremely strong harmonics right up to, and including, 32 Mc/s. Adjustment of the fundamental frequency is provided by the preset capacitor $C_1$.

In the writer's case, the aerial input to the operating position is fed via a length of 75Ω coaxial cable to the switch $S_{1(a)}$. This facility has been included since experience has shown that a greater ease of reading the frequency points may be obtained when the aerial is switched out of circuit. In this manner, only the marker points can be heard when operating the unit with a receiver, thereby eliminating possible errors with beats obtained from broadcast stations.

In position 1 of $S_{1(a)}$, the aerial input is fed direct to the aerial tuning unit, the preselector input or the receiver input, as applicable to individual installations. In positions 2 and 3, the unit is functioning and the aerial input is earthed to chassis. In position 1 of $S_{1(b)}$, the grid of $V_1$ is connected direct to chassis thereby rendering the stage inoperative. The relatively high values of $R_1$ and $R_2$ prevent excessive dissipation under this condition. At positions 2 and 3, the oscillator is allowed to function.

In positions 1 and 2, $S_{1(c)}$ isolates the 10 kc/s multivibrator, an ECC83 double triode, from the stabilised h.t. supply. In position 3 the multivibrator stage is connected to the h.t. supply and thus allowed to function.

From the above, it will be seen that in position 1, the aerial input is fed direct to the unit output whilst the 100 kc/s oscillator and 10 kc/s multivibrator are inoperative. In position 2, the aerial input is earthed and disconnected from the output whilst the 100 kc/s oscillator is brought into operation, the 10 kc/s multivibrator still being switched out of circuit. In position 3, both the 100 kc/s oscillator, and the 10 kc/s multivibrator are functioning, the latter being locked to the fundamental frequency generated by $V_1$. Also, the aerial input is still earthed to chassis and disconnected from the unit output.

$V_1$ is provided with an internal screen, pin 6, and this *must* be externally connected to pins 1, 3, 9 and the chassis. The values of the components associated with $V_1$ have been carefully calculated to produce stable and efficient operation and these should be adhered to by intending constructors. All components used in this unit should be of the best quality and exhibit the tolerances shown in the Components List.

The anode of $V_1$ (pin 7) offers two outputs. The first passes through $C_x$ and supplies the necessary coupling to the output of the unit. The capacitor $C_x$ is formed by wrapping 6 turns of a short length of p.v.c. covered lead-out wire of $C_5$ which connects to the anode.

The second output, via $C_5$, is that to the 10 kc/s multivibrator stage, $V_2$. Potentiometer $R_4$ is a chassis mounted component whose function, when correctly adjusted, is to control the input to the grid of $V_{2(a)}$ such that 9 beats are obtained between two adjacent 100 kc/s points.

The multivibrator consists effectively of two resistance capacitance coupled amplifier stages, the outputs being coupled back to each other and resulting in the triodes

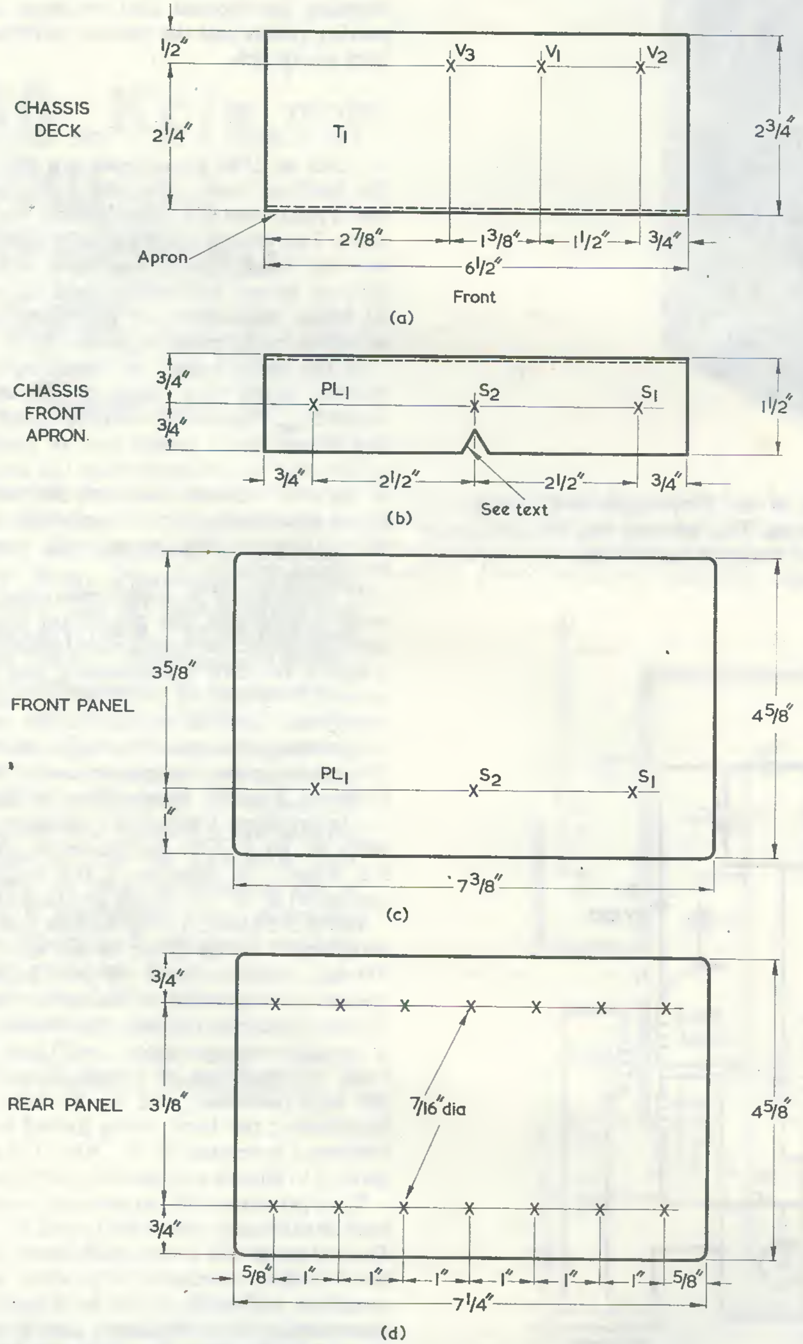


*Fig. 2 (a). Plan view of the chassis deck with drilling dimensions. The chassis is L-shaped and has only one apron. (b). Drilling dimensions of the chassis apron. The inverted V-shaped cut-out is necessary to give clearance when securing the diecast front panel to the box. (c). Drilling details of the diecast box front panel. (d). The diecast box rear panel, showing the drilling dimensions of the ventilation holes. Note here that the outside measurements of the rear panel differ from those of the front panel.*

## COMPONENTS

*Resistors*
($\frac{1}{2}$ watt 5% unless otherwise stated)

| | |
|---|---|
| $R_1$ | 47kΩ |
| $R_2$ | 100kΩ |
| $R_3$ | 220kΩ |
| $R_4$ | 20kΩ pot. lin. |
| $R_5$ | 10kΩ |
| $R_6$ | 10kΩ |
| $R_7$ | 5·1kΩ |
| $R_8$ | 5·6kΩ 3 watt |
| $R_9$ | 4·7kΩ 2 watt |

*Valves*

| | |
|---|---|
| $V_1$ | EF80 |
| $V_2$ | ECC83 |
| $V_3$ | OA2 |

*Valveholders*
2 off B9A with centre spigots
1 off B7G with centre spigot

*Chassis*
L-shaped, $6\frac{1}{2}$ x $2\frac{3}{4}$ x $1\frac{1}{2}$in (H. L. Smith & Co. Ltd.)

*Cabinet*
Eddystone Die-Cast Box, type 6357P (Home Radio Ltd., Cat. No. E903).

*Tagstrips*
1 off 3-way end tag earthed, 1 off 5-way centre tag earthed

*Rubber Mounting Feet*
Grey (4 off) (H. L. Smith & Co., Ltd.)

*Capacitors*

| | |
|---|---|
| $C_1$ | 140pF trimmer |
| $C_2$ | 200pF silver-mica |
| $C_3$ | 200pF silver-mica |
| $C_4$ | 0·01μF paper or plastic foil |
| $C_5$ | 5pF silver-mica |
| $C_6$ | 2,200pF paper or plastic foil |
| $C_7$ | 2,200pF paper or plastic foil |
| $C_8$ | 16μF, electrolytic, 350V wkg |
| $C_9$ | 8μF, electrolytic, 350V wkg |
| $C_x$ | See text |

*Switches*

| | |
|---|---|
| $S_{1(a),(b),(c)}$ | 4 pole, 3-way, miniature rotary |
| $S_2$ | s.p.s.t., toggle |

*Panel Lamp Assembly*
6·5V, 0·15A, type LES (Green) (H. L. Smith & Co. Ltd.)

*Rectifier*

| | |
|---|---|
| $D_1$ | BY100 |

*Mains Transformer*
250V 60mA, 6·3V 1·5A, type 6BR10 (H. L. Smith & Co., Ltd.)

*Crystal*
100 kc/s, vacuum mounted
(Electroniques Ltd., Cat. No. 168F 12991B)

*Knob*
Spun Aluminium (H. L. Smith & Co., Ltd.)

*Miscellaneous*
4 and 6BA nuts and bolts, p.v.c. covered wire, solder, Panel Sign Transfers Set No. 3 (Data Publications Ltd.), coaxial cable (75Ω) and sockets.

alternately driving each other from the conducting to the non-conducting states, the rate at which this occurs being determined by the time constants of the coupling capacitors and grid resistors.

For stable and efficient operation of the circuit, it is essential that a stabilised voltage supply be included in the circuit. This is provided by the OA2 stabiliser tube, $V_3$, together with the required voltage dropping resistor $R_8$.

The components $C_8$, $R_9$ and $C_9$ provide smoothing of the d.c. supply from the BY100 silicon rectifier. The mains transformer $T_1$, is a small fully shrouded component with secondaries rated at 250V, 60mA and 6·3V, 1·5A. Serving admirably in this half-wave circuit, the type number for the transformer quoted in the Components List should be adhered to for reasons of physical size.

The panel lamp assembly, $PL_1$, is connected from the live side of the heater winding to chassis and provides a panel indication showing whether the unit is on or off.

The a.c. mains input is via a 3-core cable and should be connected to the circuit as shown in Fig. 1, the mains plug being fitted with a 1·5A fuse. The live wire of the mains cable should be connected to the panel mounted on/off switch $S_2$.

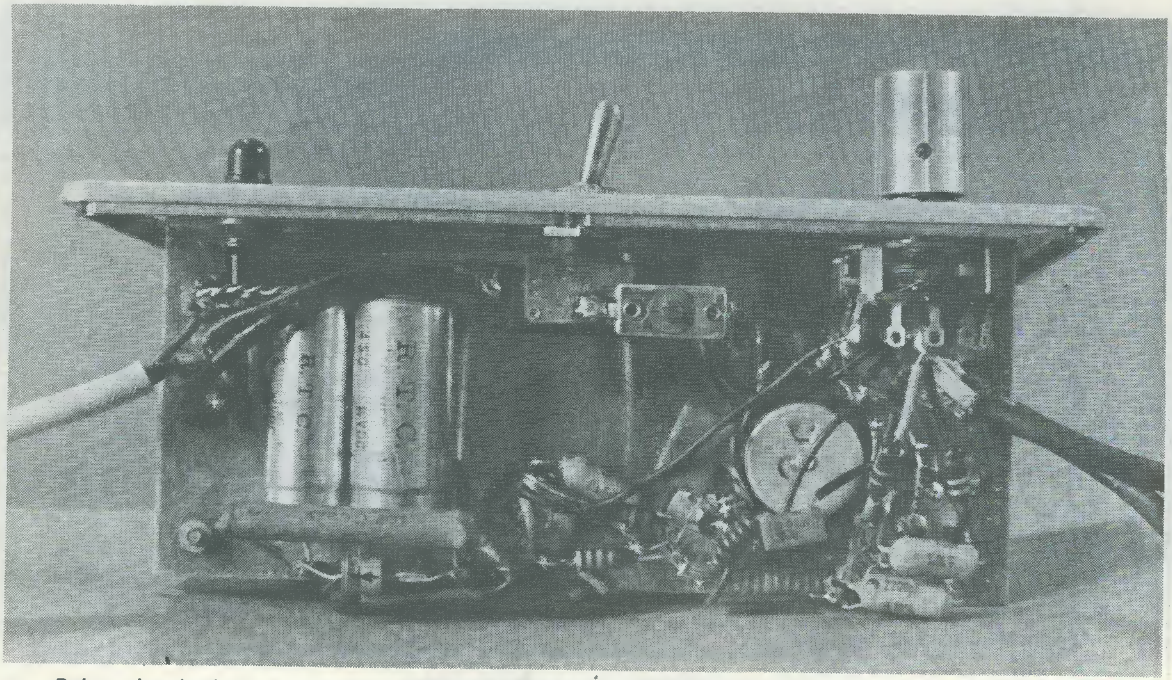
### CONSTRUCTION—DRILLING DETAILS

Fig. 2 (*a*) shows the drilling dimensions for the chassis deck. It should be noted here that the chassis is L-shaped having only a front apron. The mains transformer $T_1$ should be mounted flush with the left-hand edge of the chassis deck, the component itself being used as a template when marking out the four fixing holes ($\frac{1}{8}$in) and the two holes ($\frac{1}{4}$in) required to take its wires through the chassis deck. These latter two holes should be fitted with rubber grommets. $T_1$ should be later mounted into position such that the two black wires are nearest the left-hand edge of the chassis. The holes for $T_1$ may be drilled immediately after marking out.

The holes for $V_1$, $V_2$ and $V_3$ valveholders should next be marked out. They may be cut out with chassis cutters of appropriate size. The two mounting holes for each valveholder are drilled later.

The $\frac{7}{16}$in hole required for the potentiometer $R_4$ is not shown in Fig. 2 (*a*), the position of this depending on the size of the component obtained. It should be positioned in front of and midway between $V_1$ and $V_2$, being as near to the two valveholders as possible.

The crystal is fitted with flying leads and two holes ($\frac{1}{8}$in) should be drilled to take these below the chassis. The



*Below-chassis view showing the method of mounting the preset capacitor $C_1$ and the layout of components.*

position of the vacuum-mounted crystal may be clearly seen from the above-chassis illustration. The two holes should be $\frac{1}{8}$in apart from each other.

Fig. 2 (*b*) shows the drilling dimensions of the chassis deck apron. The holes for $PL_1$, $S_2$ and $S_1$ should be $\frac{7}{16}$in diameter. The cut-out shown below the $S_2$ position should be $\frac{3}{8}$in deep and $\frac{1}{2}$in wide, this being necessary to clear the lower centre fixing bolt of the front panel once the chassis is secured to the panel.

Prior to fitting any components to the chassis, ensure that the bottom edge of the front apron sits on the inside ledge of the front panel with the V-shaped cut-out clearing the panel fixing bolt hole. Placing the chassis such that the ends are equidistant from the edges of the front panel, and using the chassis apron as a template, mark the three panel holes on the *rear* of the panel. Drill these three holes $\frac{7}{16}$in diameter, see Fig. 2 (*c*).

As shown in Fig. 2 (*d*), the rear of the diecast box requires to be drilled with a series of ventilation holes. At the top of the rear panel, and in a horizontal line $\frac{3}{4}$in from the top of the case, drill a series of $\frac{7}{16}$in holes, the first hole being drilled in the centre of this line with three holes each side, all the holes being 1in apart.

At the bottom of the case, in a line $\frac{3}{4}$in above the bottom drill a further seven holes, each $\frac{7}{16}$in diameter, exactly below the corresponding holes at the top of the case. Three of the lower holes are later used for the a.c. mains input cable, and the aerial input and oscillator output coaxial cables.

The bottom of the case should now be fitted with four rubber mounting feet, using self-tapping screws for securing purposes. The positions of the feet are a matter of personal preference.

## MOUNTING THE COMPONENTS

Mount $T_1$ into position as previously described, feeding the wires through the grommeted holes and using four 4BA nuts and bolts. It should be noted here (see below-chassis illustration) that the two tagstrips are secured to the underside of the chassis by means of two of the $T_1$ securing bolts.

The 3-way tagstrip is associated with the a.c. mains input cable, and is secured into position by the front bolt nearer the outer edge of the chassis. The 5-way tagstrip is secured by the rear bolt nearer the hole for $V_3$.

Secure into position $V_3$ valveholder, after first drilling two mounting holes ($\frac{3}{32}$in) positioned such that tags 1 and 2 of $V_3$ are nearest the rear of the chassis. The valveholder is mounted with two 6BA nuts and bolts.

Similarly deal with the valveholder for $V_1$, ensuring that tag 7 is nearest the rear edge of the chassis. Fit a chassis solder tag under the nut nearest $V_3$.

Deal next with the valveholder of $V_2$, and position this such that tag 3 is nearest the rear edge of the chassis. Secure under the nut nearest the rear edge a chassis solder tag.

Mount into position potentiometer $R_4$ such that its three tags are located nearest the $V_2$ edge of the chassis without fouling $V_2$ valveholder tags.

Present the chassis to the front panel and secure these together by mounting into position the three front panel components, $S_1$, $S_2$ and $PL_1$. Note that the on/off switch $S_2$ is mounted such that its two solder tags are nearest $PL_1$.

## WIRING-UP

Commence this process by first wiring-up the power supply section. It is not proposed to describe the wiring-up process in any great detail, and only those points which the writer considers require further explanation will be dealt with here. All wiring inside the unit should be carried out with p.v.c. covered wire.

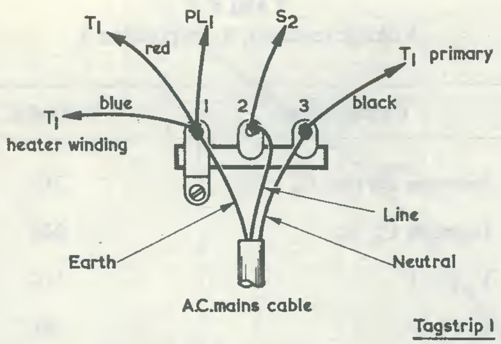


*Fig. 3. Showing the 3-core a.c. mains input cable soldered to tagstrip 1.*

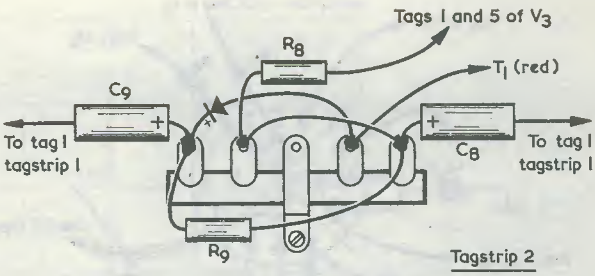


*Fig. 4. The soldered connections to tagstrip 2. Note that this drawing is presented in "exploded" form for purposes of clarity and does not show the components either to scale or in their true positions.*

Connect the a.c. mains cable to tagstrip 1 as shown in Fig. 3. The remaining black wire from $T_1$ primary should be soldered to the free tag of $S_2$.

The two blue p.v.c. covered wires from $T_1$ should be cut to length (as will now be detailed), the enamelled covering removed with a penknife, and the wire ends tinned. One lead is soldered to a tag of $PL_1$ (it does not matter which tag is used). The remaining blue p.v.c. covered wire is connected to tag 1 of tagstrip 1, as shown in Fig. 3. Also, from tag 1 of tagstrip 1, solder a short length of wire to the remaining tag of $PL_1$. The blue p.v.c. covering on the unwanted lengths of wire from the transformer should be saved for later use as insulation on component wire ends when these are soldered into position.

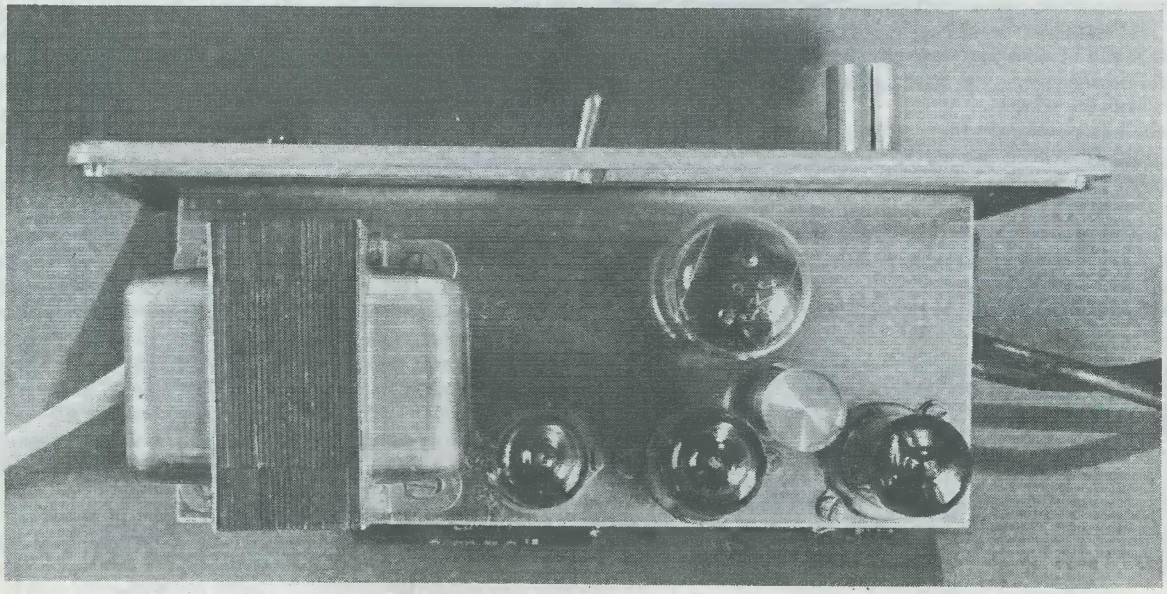
A length of p.v.c. covered wire should next be connected to that tag of $PL_1$ to which the $T_1$ blue wire was soldered. Its other end is connected to tag 5 of $V_1$ valveholder and from there to tags 4 and 5 of $V_2$.

The remainder of the power supply is connected to the various tags of the 5-way tagstrip as shown in Fig. 4. This diagram is presented in "exploded" form for purposes of clarity and the position of the components should be ascertained from the illustration of the underside of the chassis.

Great care should be taken when wiring-up the power supply stage to ensure that no wire or component carrying h.t. potential makes contact with the chassis or any other earthed point. Additionally, it should be borne in mind that the unit, when wired-up, will be contained within a metal case. It should be ascertained that no contact with the metal case is possible when the chassis and panel are secured within it.

The remainder of the components associated with $V_1$ and $V_2$ are suspended in the wiring, the wire ends of these components being cut to length and tinned prior to soldering into position. The below-chassis illustration assists in showing the method of construction and the positions of the components.

In order to obviate several lengths of wire being soldered into position for earthing purposes at each volveholder the method adopted by the writer was to (a) connect,



*Above-chassis view. At left is $T_1$, with the valves in the sequence $V_3$, $V_1$ and $V_2$. The potentiometer spindle is shown fitted with a small optional knob for adjustment purposes and located in a position mid-way between $V_1$ and $V_2$. The vacuum-mounted crystal is nearest the front panel.*

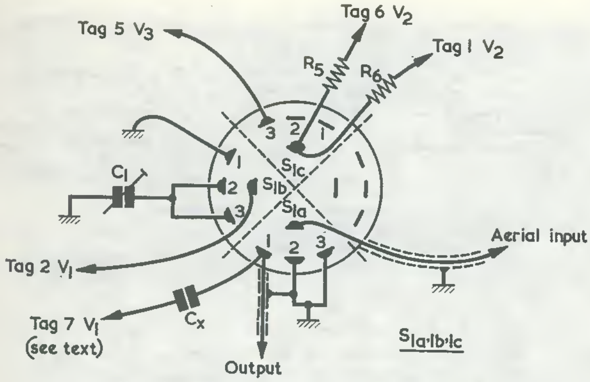


*Fig. 5. The 4-pole, 3-way switch $S_1$(a) (b),(c) shown with the tags pointing towards the reader (rear view of the component) and the required soldered connections.*

with a short length of bare wire, the central metal spigot of each valveholder to chassis and next (b) bend the appropriate valveholder tags so that they made contact with the spigot and then solder these all together. Thus, when dealing with $V_1$ valveholder, tags 1, 3, 4, 6 and 9 are each soldered to the metal spigot, which is itself connected to the adjacent chassis solder tag by a short length of bare wire. With some types of valveholder, however, this approach is not possible as the bending may result in the tags being broken. When such valveholders are used, the earthing wires to the appropriate tags may travel radially from the centre spigot. Bare wire may be used here.

The position of the preset capacitor $C_1$ may be clearly seen from the illustration, one end of this component being soldered to the metal body of switch $S_2$ and the other end being connected to one of the crystal flying leads and to tags 2 and 3 of $S_{1(b)}$—see Fig. 5.

One final point—the metal case of the BY100 rectifier must *not* make contact with any other component or tag.

The wiring to switch $S_{1(a)\ (b)\ (c)}$ is shown in Fig. 5. From this it will be seen that one section of the switch is unused. In this diagram the switch tags are shown pointing towards the reader.

As has previously been stated, the coupling capacitor $C_x$ (see Fig. 1) is formed by wrapping 6 turns of p.v.c. covered wire around the wire end of $C_5$ which connects to the anode of $V_1$.

The crystal unit specified—see Components List—is supplied with two flying leads. These leads should be cut to length and then covered for almost their entire length with systoflex so that the wires do not make contact with the chassis. Prior to soldering these two leads into circuit after passing through the chassis, they should be pulled taught, without at the same time applying undue strain. When this has been done, it will be found that the base of the crystal unit will sit squarely on the chassis deck. The crystal glass envelope may now be secured into position by the application of a few dabs of clear Bostik or other similar adhesive.

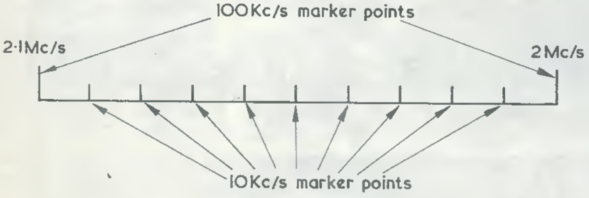


*Fig. 6. With the 10kc/s multivibrator switched into circuit, 9 beats should be heard between 2 and 2·1Mc/s when $R_4$ is correctly adjusted.*

**TABLE**

Voltage readings, $S_1$ in position 3

| Circuit point | Volts d.c. |
|---|---|
| Junction BY100, $C_9$ | 315 |
| Junction $C_8$, $R_9$ | 240 |
| $V_2$ pin 1 | 115 |
| $V_1$ pin 7 | 93 |
| $V_1$ pin 8 | 72 |

Once construction of the unit has been completed, the diecast case may be sprayed with Yukan Self Spray enamel—see advertisement in this issue—or painted in any colour of the reader's choice. Once this coat has dried, the Panel Sign wording and figures, as shown on the front panel illustration may be applied. These Panel Signs are supplied with Set No. 3.

## TESTING AND ALIGNING

Having completed construction and with the circuit wiring checked and rechecked, testing and aligning may proceed. A voltage Table is shown herewith and similar readings should be obtained, within plus or minus 10% by those readers equipped with a voltmeter.

The communications receiver, once it has attained its normal working temperature, should be set to the 5 Mc/s position and the MSF transmission on this frequency tuned to exact resonance with the receiver adjusted to its most selective state. When the frequency sub-standard unit has been allowed to warm up, the preset capacitor $C_1$ should be adjusted such that an exact resonant beat is obtained. It is often of assistance here to switch into circuit the receiver b.f.o., this being set to the zero beat position. Once $C_1$ has been correctly set, no further adjustments need to be made to this component.

Tune the receiver next to, say, 2 Mc/s, using the 100 kc/s beats to locate this frequency. Switch on the 10 kc/s multivibrator, and adjust $R_4$ such that 9 beats are heard *between* 2 and 2·1 Mc/s—making eleven beats in all—see Fig. 6. The foregoing should be carried out by operating the bandset control only. The frequency sub-standard unit is now working correctly.

Disconnect the mains supply and fit the unit into the diecast box, passing the appropriate leads through the holes in the rear. When the unit is finally secured in the box, reconnect the mains and switch on. Allow the unit to regain its working temperature, and then finally re-check against MSF.

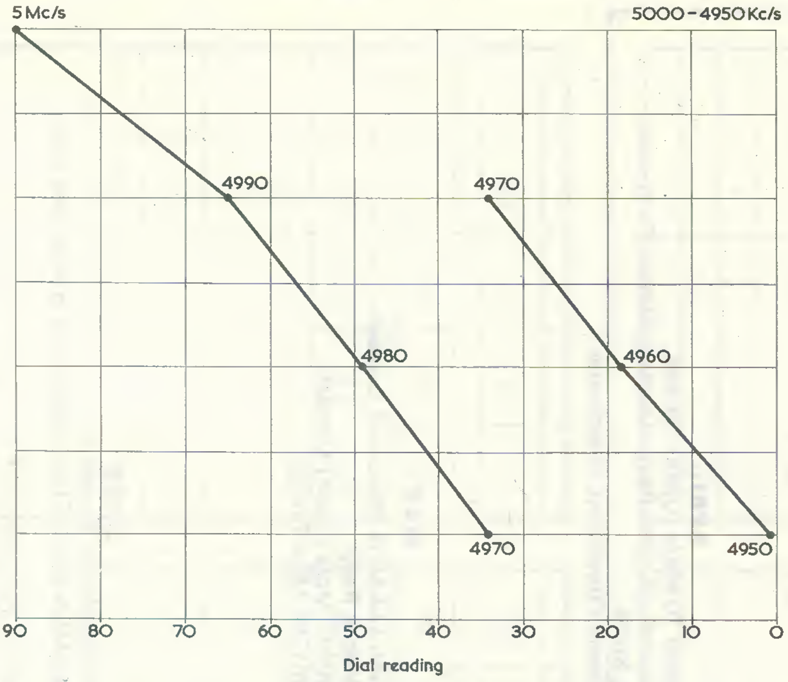


*Fig. 7. A graph obtained by plotting bandspread dial readings against the 10kc/s marker points.*

## OPERATION

In operation, the frequency sub-standard may be used not only for lining up the receiver to a particular frequency or band edge but also in the preparation of bandspread dial readings against frequency with the aid of the 10 kc/s multivibrator. A pad of suitable graph paper should be obtained, that used by the writer having a scale area of 9 x 7in, being scaled in 1in squares and sub-divided into 10ths of an inch. However, this type of paper may not be satisfactory in all individual cases, depending on the number of divisions into which the bandspread dial is marked. Should the bandspread dial be marked from 0 to 100, then the paper obtained should have a scale area greater than that just described.

A specimen graph is illustrated in Fig. 7. Along the bottom of this are entered the bandspread dial readings, i.e., 0, 10, 20, 30, etc., and the 10 kc/s points plotted from upper left to lower right in order of descending frequency. Only the main graph rules are shown in this diagram, the fainter rules—ten to the inch—are not included for reasons of clarity. Similarly, only the 10 kc/s points are shown in Fig. 7, but in fact 1kc/s points are interpolated and marked on the actual graph used by the writer. With the aid of this graph, any transmission between the limits 4950 to 5000 kc/s (4·95 to 5 Mc/s) may be located with respect to frequency.

A number of these sheets may be prepared covering the complete range of the receiver, or graphs may be drawn up for those broadcast and amateur bands in which the operator is particularly interested. These sheets may then be numbered consecutively, in the right-hand corner, and placed in order of frequency within a clear plastic folder. When operating over any selected range of frequencies, the appropriate graph is then placed on top of the remainder and read through the clear plastic cover. In this manner the graphs themselves are protected and kept clean.

In the sequence of ancillary equipments from aerial to receiver as used by the writer—i.e. aerial tuning unit and preselector—the crystal oscillator is inserted between the aerial and the aerial tuning unit.

Having the oscillator in this position confers the advantage that 100 kc/s signals are available at any point to enable the appropriate ancillary equipment to be rapidly brought into line, maximum transfer of signal being indicated on the receiver S-meter. The operator can then be assured that his equipment is functioning at maximum efficiency at the frequency chosen.

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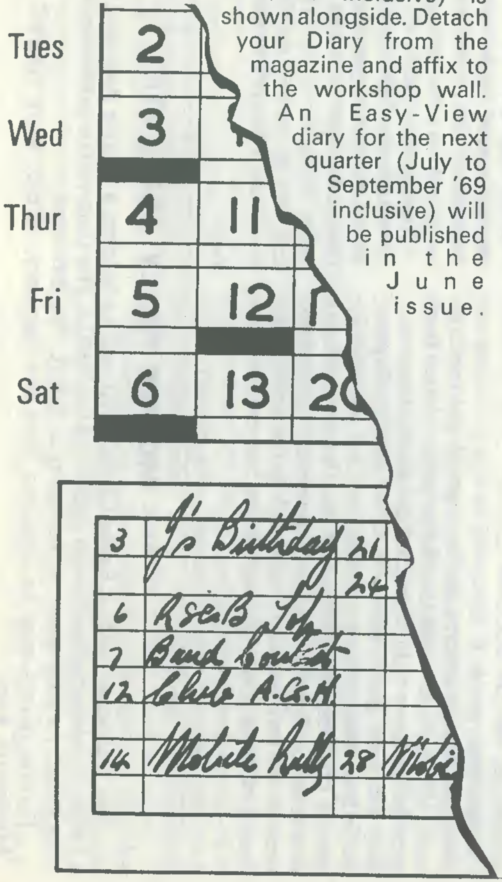
## MOBILE RALLY AND FETE

The Maidstone YMCA Radio Club G3TRF will be holding a Mobile Rally and Fete on Sunday, 1st June, 1969, to celebrate the Golden Jubilee of the YMCA. The Club will be operating an Ex Station under the call GB3YMC for one week, culminating in N.F.D. 7th–8th June.

Further details may be obtained from the Secretary, W.E.B. Kent, G8BVG, 72 Bower Mount Road, Maidstone, Kent.

# HOW TO MAKE FULL USE OF YOUR DIARY

Underline the dates of both personal and radio events in which you are interested or concerned, as shown in the illustration below, and enter brief details of these in the Diary Notes. A list of forthcoming events of radio interest taking place during the second quarter (April to June inclusive) is shown alongside. Detach your Diary from the magazine and affix to the workshop wall. An Easy-View diary for the next quarter (July to September '69 inclusive) will be published in the June issue.



# SUGGESTIONS FOR YOUR EASY-VIEW DIARY

## APRIL

| | |
|---|---|
| 12–13 | RSGB Second 70 Mc/s (Open) Contest. |
| 20 | North Midlands Mobile Rally, Drayton Manor Park, near Tamworth, Staffs. |
| 27 | RSGB Bellevue Convention, Manchester. |

## MAY

| | |
|---|---|
| 3–4 | RSGB Fourth 144 Mc/s (Portable) Contest |
| 18 | Northern Mobile Rally |
| 24–25 | RSGB First 432 Mc/s (Open) Contest. |
| 24–25 | RSGB First 1296 Mc/s Contest |

## JUNE

| | |
|---|---|
| 1 | Amateur Radio Mobile Society Rally |
| 1 | Maidstone YMCA Radio Club Mobile Rally & Fete (see page 517) |
| 7–8 | RSGB National Field Day (H.F.). |
| 22 | RSGB Second 432 Mc/s (Portable) Contest. |
| 29 | Longleat Mobile Rally, Longleat Park, near Warminster, Wilts. |

# THE RADIO CONSTRUCTOR'S 'EASY VIEW' DIARY

SECOND QUARTER 1969

## APRIL

| | | | | | |
|---|---|---|---|---|---|
| Sun | | 6 | 13 | 20 | 27 |
| Mon | | 7 | 14 | 21 | 28 |
| Tues | 1 | 8 | 15 | 22 | 29 |
| Wed | 2 | 9 | 16 | 23 | 30 |
| Thur | 3 | 10 | 17 | 24 | |
| Fri | 4 | 11 | 18 | 25 | |
| Sat | 5 | 12 | 19 | 26 | |

## MAY

| | | | | | |
|---|---|---|---|---|---|
| Sun | | 4 | 11 | 18 | 25 |
| Mon | | 5 | 12 | 19 | 26 |
| Tues | | 6 | 13 | 20 | 27 |
| Wed | | 7 | 14 | 21 | 28 |
| Thur | 1 | 8 | 15 | 22 | 29 |
| Fri | 2 | 9 | 16 | 23 | 30 |
| Sat | 3 | 10 | 17 | 24 | 31 |

## JUNE

| | | | | | |
|---|---|---|---|---|---|
| Sun | 1 | 8 | 15 | 22 | 29 |
| Mon | 2 | 9 | 16 | 23 | 30 |
| Tues | 3 | 10 | 17 | 24 | |
| Wed | 4 | 11 | 18 | 25 | |
| Thur | 5 | 12 | 19 | 26 | |
| Fri | 6 | 13 | 20 | 27 | |
| Sat | 7 | 14 | 21 | 28 | |

DIARY NOTES

# ELECTRONIC NEWS

## TRUST IN INTERNATIONAL BROADCASTING

A public lecture was given recently by the BBC's Director of External Broadcasting, Mr. Charles Curran, who, as has been recently announced, is to be the BBC's next Director-General. His subject was broadcasting overseas and the aims and policy of the BBC External Services.

Mr. Curran recalled the various major political changes since the BBC began broadcasting overseas thirty years ago—the second world war, the cold war that followed, the Hungarian rising, the Suez crisis, and last summer, the invasion of Czechoslovakia. He then turned to the future role of the BBC's overseas service and the significance of broadcasting now that Britain is ceasing to be a world military power. "Power based on physical resources is one thing", said Mr. Curran, "influence can be based on other factors, and I believe that those other factors Britain has in adundance".

His case had been made a little while ago by Senator William Fulbright. "Britain has bequeathed a great legacy to much of the world", said the senator, "the legacy of her own experience in constitutional government, peaceful evolution and the orderly accommodation of diverse interests within the society. When the fleets and bases have been dismantled, there will remain something much more valuable and more durable. The legacy of British ideas which other nations have found worthy of imitation. To my mind, the setting of a decent example is probably the greatest single service most likely of good effect, least susceptible to corruption, that any one people can perform for another."

What then, must the BBC do to make sure that the influence of Britain is properly brought to bear on the opinion of the world audience? How should it speak to those who live under Communist domination in Eastern Europe, to those in the developing countries, and to those in countries suffering uncertainties and strife? "It seems to me," said Mr. Curran, "there is one central element which will satisfy all those needs. It is a comprehensive and accurate service of news, brought to the listeners either by us or by the news agencies."

"It is very easy if one lives in a Western country with reasonably free access to information to forget that over a large part of the world, for reasons either of censorship or of the technical inadequacy of communication, the availability of news is very limited indeed. Reliable news is in short supply and greatly wanted. And it is the unique function of the BBC that it can convey this news, and convey it with authority."

Why is it that the BBC is believed? There is one very simple historical reason, Mr. Curran explained. "Our broadcasting had its origin at a time when adversity was our expectation. We reported defeats, we reported them accurately, and when the time came to report victories we were believed, because people knew we had been honest about our failures. To have credibility, you must have a history, a credit rating with the listening public. We must never depart for one instant from the standards of objectivity and of accurate reporting which we have set ourselves."

## CONFERENCE—DIGITAL SATELLITE COMMUNICATION

A major impact on all aspects of satellite communication over the next five years is expected to result from the introduction of digital techniques, especially pulse code modulation. In recognition of the economic and technical implications of this, Intelsat, the international consortium of over 60 nations, is to sponsor a conference entitled "Digital satellite communication." The IEE is to co-sponsor the conference which will be held at Savoy Place, London WC2 from the 25th to 27th November, 1969.

The aim of the conference is to provide a forum for the presentation and exchange of information on digital-communication techniques, and the programme will embrace: (a) systems aspects including performance targets and comparisons with analogue systems; (b) coding and modulation; (c) signalling and switching including interface with terrestrial networks; (d) demand assignment and multiple access techniques; (e) error control; (f) interference aspects.

The programme will also include some invited papers from international authorities in this field.

The technical programme committee invite contributions from all nations, and intending authors should submit synopses written in English (preferably) or French of 500 to 100 words in length by the 1st April, 1969.

Further details of the conference and registration forms will be available in due course from the Intelsat—IEE Joint Conference Secretariat, Savoy Place, London WC2, England.

**SOLID-STATE AUDIO GENERATOR**
*(continued from page 509)*

## CALIBRATION

The final stage of construction is that of calibration, with the main dial calibrated in 1 kc/s steps to 20 kc/s., and the "bandspread" dial in 50 c/s steps to 500 c/s with 25 and 75 c/s points added for convenience.

Calibration is greatly facilitated if at least two "standard" frequencies are available, these most conveniently being 1 kc/s and 50 c/s. These are used either to synchronise the oscillator timebase, or to produce Lissajous figures.

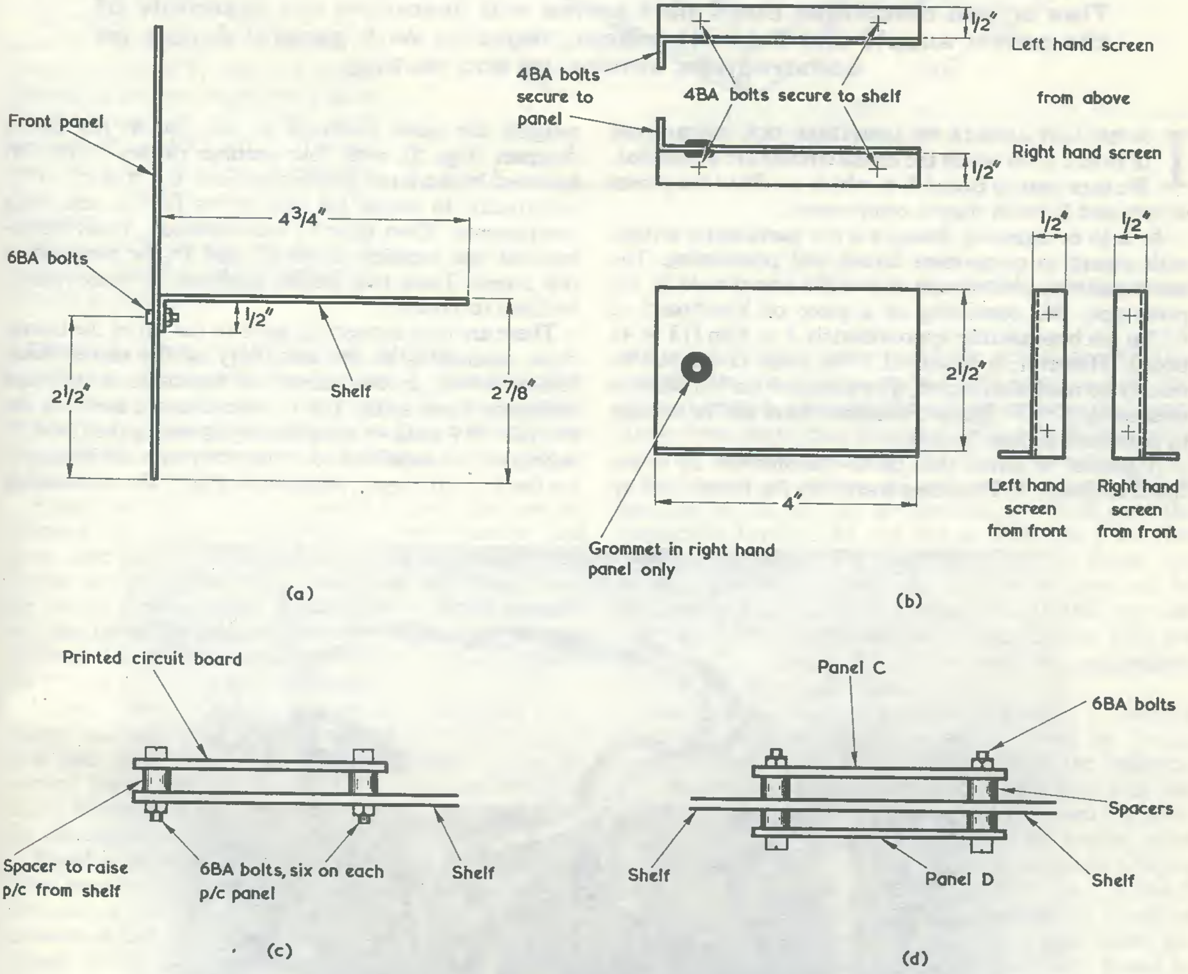


*Fig. 5 (a). Securing the shelf to the front panel*
*(b). How the left and right hand screens are made*
*(c). Panels A and C are spaced off from the shelf with six spacing washers each*
*(d). Panels C and D are mounted, above and below the shelf, with a single set of bolts and nuts*

The author used the former method, the synchronised timebase being adjusted to give one complete sine wave for 1 kc/s and 50 c/s respectively. Calibration is carried out by tuning the beat frequency generator for successive stationary sine waves, each of which will be an exact multiple of the "standard".

If the Lissajous method is used, the standard frequencies are fed to the "X" amplifier of the oscilloscope, and the generator calibrated from the resulting patterns. Lissajous patterns will be found in most text books dealing with oscilloscopes. They were also dealt with in full in "Getting the Best from your Oscilloscope" Part 1, by D. J. Griffiths, in the May 1968 issue of this journal.

Whichever method of calibration is adopted, the first step is to accurately set the zero position on both dials. This is done by adjusting the Zero Set control for zero beat, and marking the zero point on each dial. The main dial is of course calibrated with the "bandspread" set at zero and vice versa. Frequent checks should be made upon the zero setting during the actual calibration, for this is itself the reference point in checking the calibration in use. Short of damage or alteration in the respective tuning circuits the calibration should remain accurate indefinitely.

In use, frequencies above 500 c/s are obtained by simply tuning the main dial; frequencies below 500 c/s are obtained by tuning the "bandspread" control with the main dial set at zero. If both dials are used the "bandspread" setting is subtracted from that of the main dial, and in this way any frequency from 25 c/s to 20 kc/s can be readily generated, accuracy being quickly confirmed, as required, by checking the zero beat.

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# SOLID - STATE DIGITAL CLOCK Part 4

## by

## A. J. EWINS

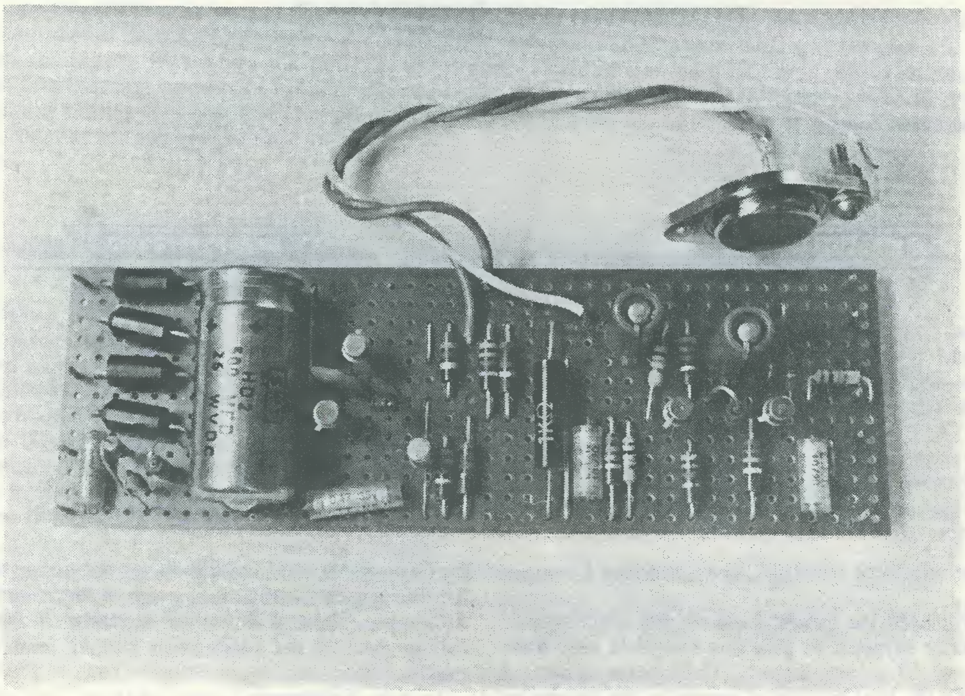
**This article concludes our 4-part series and describes the assembly of the power supply and Schmitt trigger, together with general details on construction, setting-up and testing.**

In the last article we completed our description of Board 3, on which the chime circuits are assembled. We turn next to Board 4, to which are fitted the power supply and Schmitt trigger components.

As is to be expected, Board 4 is not particularly critical with regard to component layout and positioning. The accompanying photograph shows the board used in the prototype, this consisting of a piece of Veroboard of 0·15in pitch measuring approximately 2 × 6¼in (13 × 41 holes). However, a board of 0·1in pitch could just as readily be used whereupon, if two large 0·1in Veroboards measuring 17·9 × 3¾in are obtained there will be enough to construct all four boards.

It should be noted that mains transformer $T_1$ is not fitted to Board 4. The components on the board take up roughly the same positions as they do in the circuit diagram (Fig. 5), with four rectifier diodes to the left followed by the large 500μF capacitor, $C_1$. It is left to the constructor to design his own layout for the remaining components. When Board 2 was discussed, it was recommended that rectifier diodes $D_1$ and $D_6$ be mounted to this board. These two diodes need not, in consequence, be fitted to Board 4.

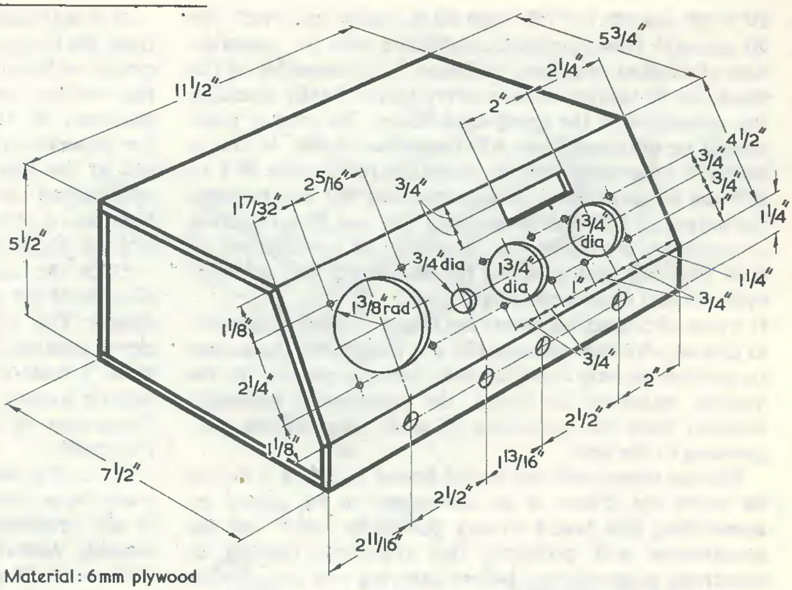
There are four connecting spills to the left of the board, these connecting to the secondary of the mains transformer which, in the completed assembly, is mounted alongside these spills. The connections are made to the 0V, 12V, 15V and 24V taps, thereby obtaining the 12-0-12V supply for the rectifier circuits together with the 3V supply for the Schmitt trigger, as shown in Fig. 5. Five connecting


*The components on Board 4, which carries power supply and Schmitt trigger circuits*

spills at the right provide the following outputs.

1. Unstabilised positive supply (not used),
2. Stabilised positive supply rail.
3. Schmitt trigger output,
4. Negative supply rail,
5. 0 volts or earth rail.

Transistor $TR_1$ is mounted on a small heat sink away from the board. Potentiometer $RV_1$ was not incorporated in the prototype, the author shunting one of the 10kΩ bias resistors ($R_7$ and $R_8$ of Fig. 5) with a suitably valued fixed resistor to obtain the correct working point. However, it is recommended that constructors fit the potentiometer in their own versions, as the setting-up process is then easier.



Material: 6mm plywood

*Fig. 20. A cabinet suitable for use with three read-out meters*

## GENERAL CONSTRUCTIONAL HINTS

Before continuing with the description of the mounting of the boards and other components in the complete assembly it is thought worthwhile to give a few general hints on the construction of the boards and the order in which they should be attempted.

Firstly, as 0·1in pitch Veroboard is used, the spacing between the copper conductors is very narrow and great care must be taken to ensure that no solder blobs bridge the gaps. Soldering irons with bits larger than ⅛in are not recommended. A good cored solder is essential and the bit of the soldering iron should be kept clean at all times. The proper copper removal tool is recommended for "breaking" the copper conductors.

When designing layouts the author's approach is to mount and solder the components on to the Veroboard first and then "break" the copper conductors in the correct places afterwards. The only care that must be taken is to ensure that a free hole is always left available for the copper conductor to be "broken" at that point.

Board 4 should be constructed first in order that the other boards can be tested as their construction progresses. The output of the positive stabilised supply should be between 9 and 10 volts and the output of the negative supply should be —9 volts at a current drain of 1mA. The best way to check the output from the Schmitt trigger is to display the waveform on an oscilloscope. This way the mark-space ratio can easily be observed. If an oscilloscope is not available the output can be checked by measuring the voltage between the collector of $TR_6$ and earth (Fig. 5) with an a.c. voltmeter connected in series with a large blocking capacitor. If the output is of the order of 1.3 volts the chances are that the Schmitt trigger is working satisfactorily.

Having constructed the power supply, Board 1 should now be attempted. It is suggested that initially binaries B1 to B6 and the monostable should be constructed and tested before progressing to the next stage. With the appropriate connections made to the power supply and Schmitt trigger, and with the trigger input to the monostable from the inverse output of binary B5 disconnected (see Fig. 1) the output from B6 should be a pulse every 1·28 seconds, or approx. 47 pulses per minute. This is because the six binaries are dividing by 64. If now the connection between B5 and M1 is made the pulse rate should increase to one every second or 60 pulses per minute. The outputs from the various binaries can be checked by using the 10 volt range of a 20,000Ω per volt voltmeter. It is worthwhile becoming familiar with the operation of binaries B1 to B6 and the monostable before continuing with the next stage.

When satisfied that the first part of Board 1 is working correctly, construction should be continued by wiring up the binaries B7 to B10, initially without the feedback and feedforward connections being made and with the inputs to the two input capacitors of B10 joined together. If this process is carried out correctly an output pulse should be obtained from B10 every 16 seconds. Output pulses from B7 to B9 will be obtained every 2, 4 and 8 seconds respectively. A stop watch is useful for checking all these times, including the one second pulse from B6. After the four binaries B7 to B10 have been found to work correctly (i.e. dividing by 16) then the feedback and feedforward connections can be made and the trigger input to B10 divided into two as shown in Fig. 1. The output from B10 should now be a pulse every 10 seconds.

Binaries B11 to B13 can next be constructed together with their feedback and feedforward connections and checked as before. The output from B13 will be a pulse every 60 seconds. It will be observed that the output pulses from binaries B10 and B13 do not have a 1:1 mark-space ratio. The output from B10 is, in fact, "off" for 8 seconds and "on" for 2 seconds, and in the case of

B13 the output is "off" for 40 seconds and "on" for 20 seconds. Having gained confidence with the construction of the first two rows of Board 1, the assembly of the third can be tackled in its entirety before finally checking the operation of the completed board. An output pulse should be obtained from B20 once every hour. As this is rather a long time to wait, checking of binaries B14 to B20 can be carried out by disconnecting the lead between the output of B13 and the input of B14 and by connecting a temporary lead from the output of B6 to the input of B14. This will give pulses at the outputs of B17 and B20 every 10 and 60 seconds respectively.

It is not, of course, necessary for Board 1 to be constructed in this step-by-step manner, but it is thought by the author to provide an easy learning and checking process for the various stages of the board, the constructor becoming familiar with the operation of each stage before progressing to the next.

Having completed and tested Board 1, Board 2 should be wired up. There is no advantage to be gained by assembling this board in any particular order and the constructor will probably feel confident enough to construct it completely before carrying out any further tests. Once it has been completed it should be tested in two stages, the order of which is not important. Consider first the binaries B21 to B25 and the AM/PM light circuit. If a one second series of pulses is fed into the input of B21 the bulbs of the light circuit should be alternately lit up every 12 seconds. The meter read-out circuit can be tested in four stages or all at the same time. No part of the circuit will suffer if any meter or any connection between the binary outputs and the read-out circuit inputs are disconnected. With the outputs, 1–7, from the binaries B7 to B13 connected to the inputs 1 to 7 of the read-out circuit and a 1mA meter connected in the seconds position, as indicated in Fig. 4, it should take 60 seconds (or 60 pulses into B7) for the meter to read from zero back to zero again. 59 seconds is full scale deflection, the sixtieth pulse returning the meter to zero. If the reader wishes to use the same type of cabinet as that employed by the writer, a seconds read-out can easily be provided by switching the hour meter between the hours position and the seconds position as required, a two way switch being all that is needed to achieve this result. (This switch may also bring into circuit suitable meter shunts, if required.)

Having checked the seconds read-out the other read-outs can be checked by connecting the remaining outputs 8–18, from the binaries B14 to B24 to the inputs 8–18 of the read-out circuit. Full scale deflection of the hour, tens-of-minute and minute meters are 11 o'clock, 50 minutes and 9 minutes respectively. The zero on the hour meter is replaced by 12.

It is advisable that the leads connecting the outputs from the binaries on Board 1 to the inputs of the read-out circuit on Board 2 should be long enough to reach between the various connecting points when the boards are mounted in their final positions. Any disconnection for experimenting or final mounting should be carried out at the Board 2 end of the leads. It will be readily appreciated that having once soldered a lead on to Veroboard, at the outputs of the binaries, it is not advisable to keep removing and resoldering it.

Once the checks on the read-out circuit have been completed the meters can be recalibrated and new scales drawn. The hour meter's scale should be divided into eleven and made to read 12, 1 to 11; the tens-of-minutes meter's scale divided into five to read 0 to 5 and the minute meter's scale divided into nine to read 0 to 9. Panel-signs or other similar figuring is ideal for marking the scales.

When the new scales have been drawn and fixed into place the accuracy of the meter readings can be checked. It will probably be necessary to shunt the meters with suitably valued resistors to obtain the correct full scale deflections. If any of the individual meter readings do not coincide with the scale markings, resistors of suitable values should be connected in parallel and/or series with the collector resistors of the read-out circuit transistors $TR_1$ to $TR_{18}$ to correct the readings. Altering the individual meter readings will affect the full scale deflections of the meters so that the addition of the correcting resistors must be carried out by trial and error until the constructor is satisfied with the results. If 1% resistors are used for the collector resistors of $TR_1$ to $TR_{18}$ it will only be necessary to correct the full scale deflection of each meter. In the author's opinion the use of 1% resistors is not justified as he only had to correct the values of four of the collector resistors when

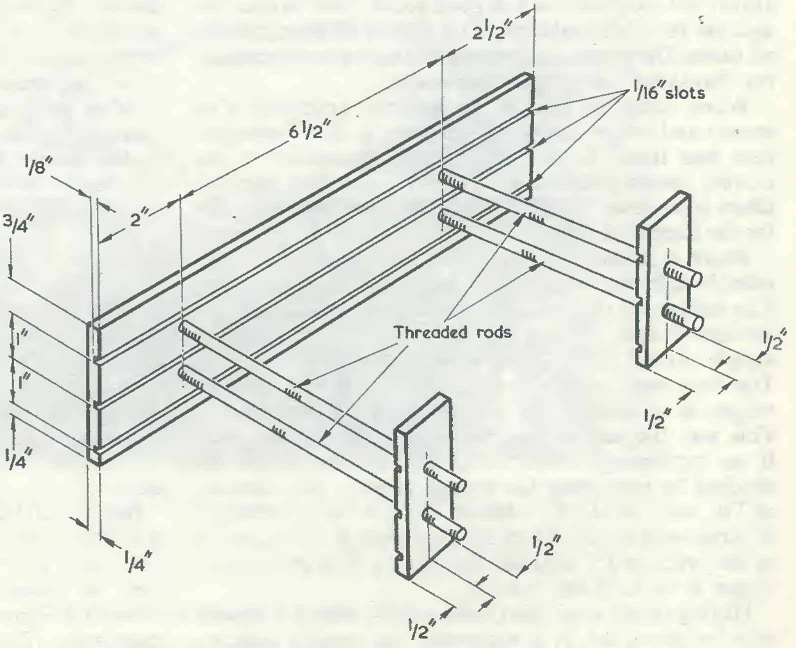


*Fig. 21. The supporting framework for Boards 1, 2 and 3*

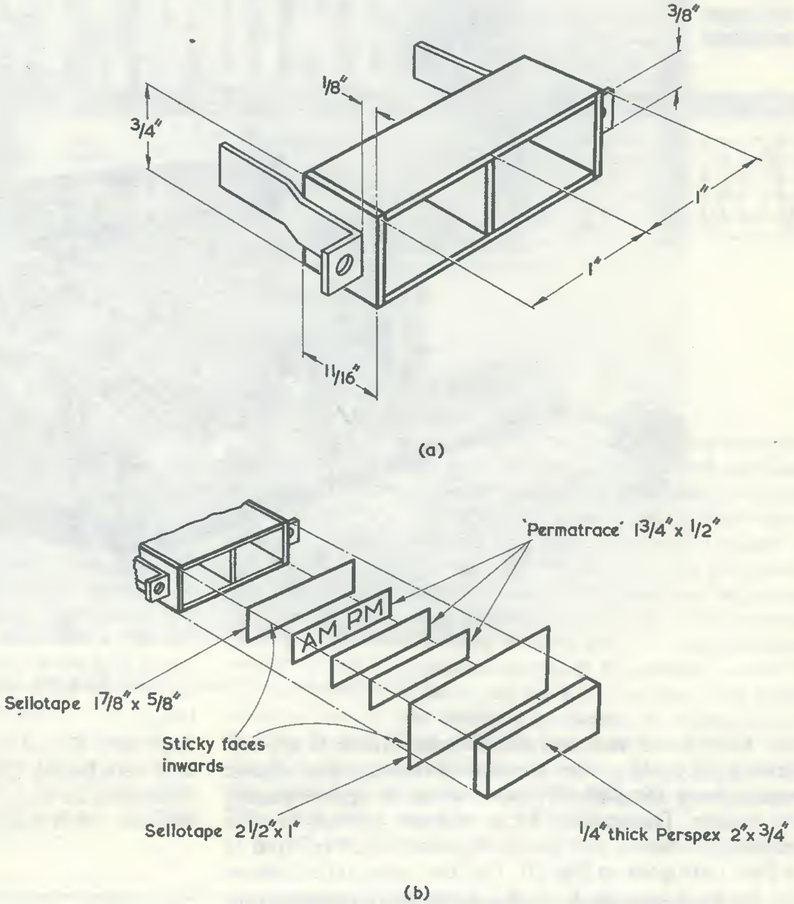


*Fig. 22 (a). Assembling the AM/PM light holder*
*(b). Adding the lettered "window" to the light holder*

the recommended 5% tolerance ones were used. With the meters rescaled and recalibrated the circuit boards 1, 2 and 4 can be interconnected and the clock allowed to run so that it can be checked for time-keeping accuracy.

With the basic circuit of the clock and the read-out circuit operating satisfactorily, the chime circuit, Board 4, should now be constructed. The ten binaries BC1, BH1 to BH4, BC2 and BS1 to BS4 are first wired up on the board, the operation of the hour binaries, BH1 to BH4, and the second binaries, BS1 to BS4, being checked for satisfactory operation before continuing with the rest of the wiring. The comparators, C1 to C4, and the OR gate are constructed next. The output of the OR gate will be at near zero volts when the outputs of binaries BS1 to BS4 are the same as the opposite binaries, BH1 to BH4, this being checked for the twelve possible conditions of the two sets of binaries. When the construction so far completed is working properly the remainder of the chime circuit building blocks can be wired up, plus all the various interconnections between them. After completion, the board must be double-checked to ensure that the copper conductors have been "broken" in the correct places and that no link exists between components that should not. This is a tedious process but is well worth the effort when the circuit operates correctly first time. To check the operation of the completed chime circuit all but the input to the binaries BC1 and BH1 should be connected up to the existing clock circuit. Upon switching on the oscillator will operate for a number of times depending on the initial state of the binaries. When the oscillator ceases operation it should be possible to restart it by connecting the input to binaries BC1 and BH1 to the negative going second pulses at the output of B6 for long enough to hear the first "chime", removing the connection as soon as it is heard. The oscillator will now operate for a number of chimes. If the circuit is operating properly, a repeat of the above instructions should produce a count of the next logical time sequence (i.e. 8 chimes if the first was 7 and so on).

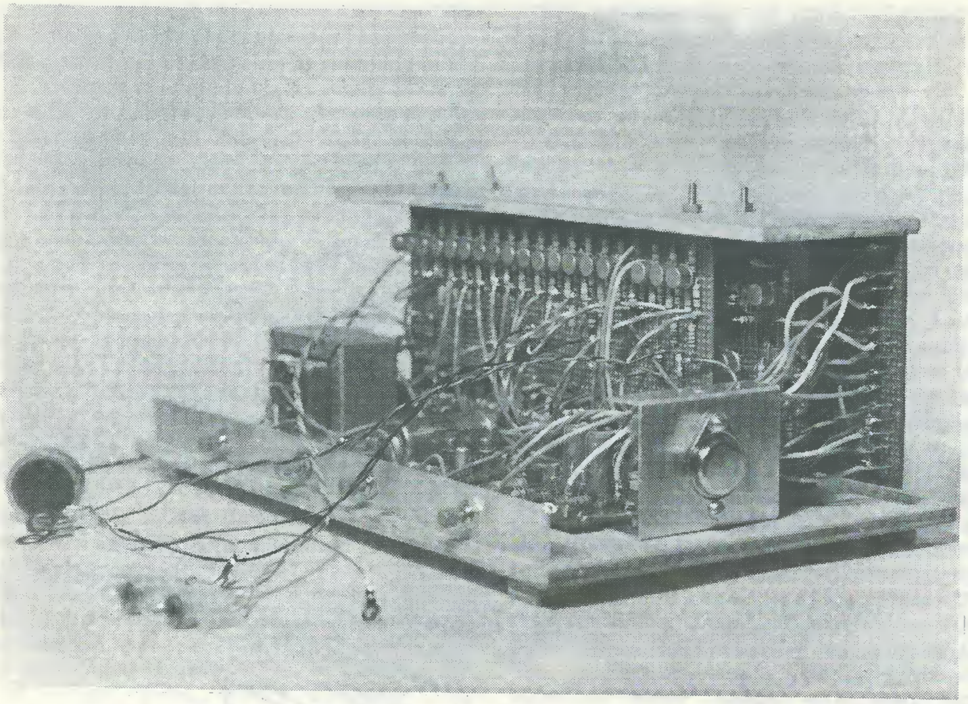
It is difficult to give any guidance on "trouble shooting" when the possible number of faults is so numerous. The author can only stress the necessity of checking that all the breaks in the copper conductors have been made in the appropriate places and that no "blobs" or "runs" of solder exist between the rows of conductors. It is certainly advisable to check the operation of the circuit boards at the various stages of construction, not progressing to the next until satisfied that what has already been constructed is working correctly.

It is to be expected that as the semiconductors are of the surplus variety they may give trouble. They should all be checked before inserting in the circuits. All the transistors (except where specific types are mentioned in the Components Lists) should have a current gain of 20 or more at an emitter current of 1mA. A suitable test circuit was given in Part 1 of this series.

As an indication of the reliability of the semiconductors used only three transistors have had to be replaced and this occurred before the clock was completed. It has at the time of writing been running for several months, though not continuously (approximately 8 hours a day) without any other trouble.

## THE CABINET

When construction is complete and the clock is functioning satisfactorily, some form of housing for all the components is needed. The size of the cabinet will, to a large extent, depend on the number and types of meter used. In the cabinet illustrated in Part 1 there are, for instance, three meters, these being Japanese SEW types, readily obtainable from electronic component stockists.



*The completed assembly viewed from the side*

The hour meter was an MR56P type, which is approximately $3\frac{1}{8} \times 3\frac{3}{8}$in, and the tens-of-minutes and minute meters were the MR45P type, which is approximately 2in square. Dimensions for a suitable cabinet to take these three meters and the microphone insert referred to in Part 1 are given in Fig. 20. The four holes at the bottom are for push-buttons $S_2$ to $S_5$. Alternative cabinets can, of course, be designed to take four meters and/or meters of different type.

The accompanying photographs show a suitable method of assembling the parts of the clock into a form suitable for fitting into a cabinet such as that of Fig. 20. The three boards are held in the framework shown in Fig. 21, the large rectangular piece of wood being at the top. The slots were made with a tenon saw, and the 1in wide pieces should be cut off from the larger piece (the extra length required having been allowed for) after the slots have been made. The threaded rods are 4BA studding about 5in long, and they pass down through the 1in wide pieces and a wooden baseboard. To this baseboard are also secured the mains transformer, Board 4 and the heat sink for $TR_1$ of the power supply. The heat sink may be an aluminium bracket with a flat surface approximately 2in square. The four push-buttons are mounted on a piece of $\frac{3}{4}$in aluminium angle. Switch $S_1$ is mounted behind the mains transformer on another piece of $\frac{3}{4}$in aluminium angle in such a manner that its toggle just protrudes through a hole in the base. Four small wooden feet are provided for the baseboard.

The three boards are mounted in the framework in the manner shown in the photographs. Board 1 is at the rear (i.e. furthest away from the mains transformer and Board 4), Board 3 is in the middle and Board 2 is at the front, with all the component sides towards the front. Note that, with Board 1, bistables B1 to B6 are at the top; with Board 3, bistables BS1 to BS4 are at the top; and with Board 2, transistors $TR_1$ to $TR_{18}$ are at the top. This enables short wiring to be given between Board 1 and the other boards.

## AM/PM LIGHT HOLDER

Constructors may have their own ideas on making up the AM/PM light holder, but a very suitable method is illustrated in Figs. 22 (*a*) and (*b*). This holder is intended for fitting to the cabinet of Fig. 20.

The light holder is made, basically, from a piece of $\frac{3}{4}$in square Paxolin tubing, $1\frac{7}{8}$in long. Two pieces of $\frac{1}{16}$in thick Paxolin were glued on the open ends with Araldite to form a completely enclosed rectangular box. With the aid of a rotary bench sander one side was completely sanded off. A centre partition was then glued inside making two compartments. Holes were drilled in the centre back of each compartment large enough to allow the 6V bulbs to pass through. Aluminium brackets, as shown in Fig. 25 (*a*), were glued to each end to support the bulb holders, which are of the clip-on type, and to enable the front of the assembly as so far constructed to lie $\frac{1}{8}$in forward of the rear of the cabinet panel.

Fig. 22 (*b*) shows the sandwich type construction of the AM/PM letter screen. Large Letroset letters were used for the lettering. "Permatrace" is a plastic type of tracing paper, and ordinary tracing paper could probably be used as a substitute. The two extra thicknesses are necessary to "hide" the lettering until illuminated from behind. The $\frac{1}{4}$in thick Perspex window is made a push fit into the panel hole and is inserted from the front and pushed flush up against the light holder.

# UNDERSTANDING RADIO

$f=\frac{1}{2\pi\sqrt{LC}}$

## Tuning Indicators

### by W. G. Morley

IN LAST MONTH'S ISSUE WE CONTINUED OUR DISCUSSION of automatic gain control systems by examining the manner in which the a.g.c. voltage is applied to the control grids of the controlled valves. Two basic methods are employed. One of these is the *parallel feed* method, in which the a.g.c. voltage is applied to the control grid via a high value resistor, d.c. isolation between the grid and its tuned coil being achieved by inserting in series a capacitor having a low reactance at signal frequencies. The other method uses the *series feed* circuit in which the a.g.c. voltage is applied to the lower end of the grid tuned coil, this end of the coil being bypassed to chassis via a capacitor having a very low reactance at signal frequencies. We also examined a.g.c. *time constant*, noting that, with domestic a.m. receivers, typical charging time constants normally lie between 0·05 and 0·2 seconds.

We shall now conclude on the subject of a.g.c., turning our attention afterwards to tuning indicators.

## LOW-COST A.G.C. SYSTEMS

It is possible to produce a.m. valve superhets intended for long and medium wave reception, or for long, medium and short wave reception, having low-cost bias and a.g.c. circuits, and a typical example is shown in skeleton form in Fig. 1. In this diagram we have a frequency changer, a double diode pentode and a triode pentode. The frequency changer is a standard valve employing normal frequency changer circuitry, and could be an ECH81. The pentode section of the double diode pentode gives i.f. amplification whilst one of its diodes functions in a common circuit to provide signal detection and an a.g.c. voltage. The other diode is unused and connects to chassis. A typical choice for the double diode pentode would be the EBF89. The triode in the third valve is an a.f. voltage amplifier, whilst the pentode is an output valve feeding the loudspeaker. This third valve could be an ECL83.

It will be apparent that the circuit offers a significant

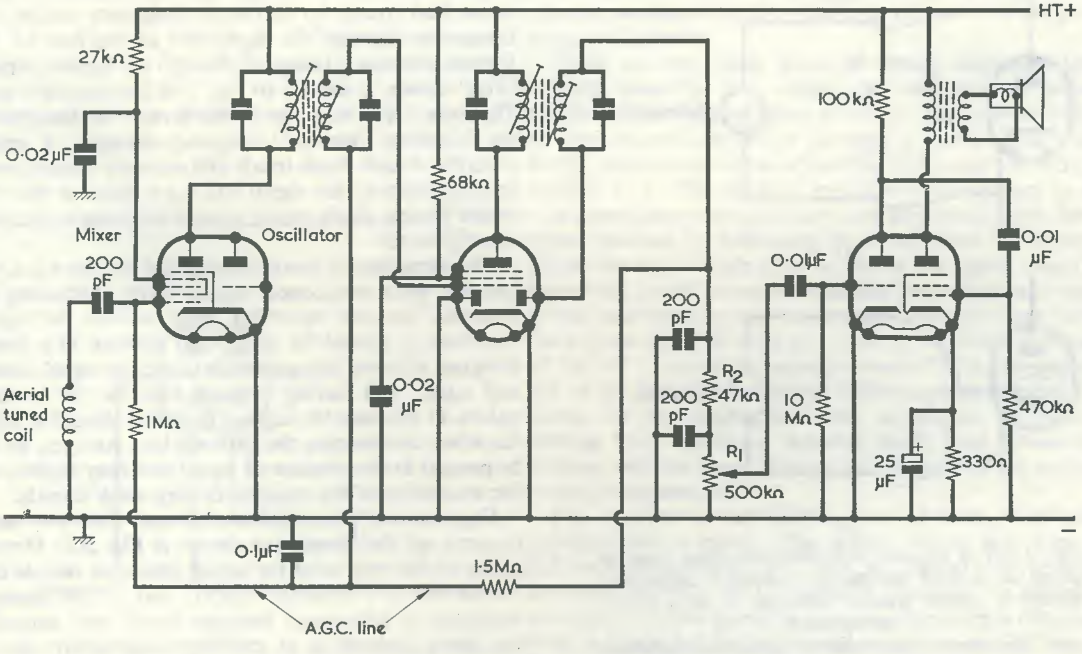


*Fig. 1. Skeleton receiver circuit illustrating the economic bias and a.g.c. circuits encountered in some low-cost domestic a.m. superhets. Component values are typical.*

economy in components because the cathodes of the first two valves simply connect direct to chassis. The cost of the cathode bias components which would otherwise be required is, in consequence, saved.

Even though the first two valves are operated without cathode bias they do not, in practice, suffer excessive dissipation. This is partly because they still receive a small bias due to contact potential in the detector diode.[1] The contact potential causes a negative potential of the order of 0·3 to 0·5 volts to be present at the diode anode relative to its cathode, and this is applied to the control grids of the preceding valves via the a.g.c. filter components. The control grids of these valves will also themselves exhibit a negative contact potential, which can assist in ensuring that a small bias is present. Another reason for stating that the working conditions in Fig. 1 are permissable is that the screen-grid feed resistors for the first two valves automatically assist in preventing excessive dissipation. A high electron current from the cathode of each of the valves causes a relatively high voltage to be dropped across its screen-grid resistor, whereupon the screen-grid takes up a low positive potential and partially limits anode current. Another point, which applies to the frequency changer valve only, is that anode current in the mixer section of the frequency changer is limited, to some extent, by the fact that the mixer oscillator injector grid will have an average negative bias due to its being connected to the grid of the oscillator section.

As soon as a receiver incorporating the circuit of Fig. 1 is tuned to a transmitted signal (or is subjected to "noise" picked up in the aerial stage) an a.g.c. voltage is developed and the first two valves function in the same manner as would have occurred had they been provided with cathode bias components.

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[1] Contact potential was discussed in "Understanding Radio" in the July, 1965 issue.

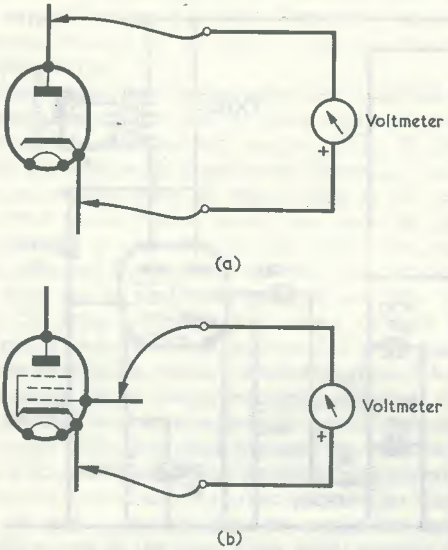

*Fig. 2 (a). A contact potential indication may be given in a high resistance voltmeter connected across a diode whose cathode is at emitting temperature.*
*(b). The same effect may be perceived between the control grid and cathode of valves other than diodes.*

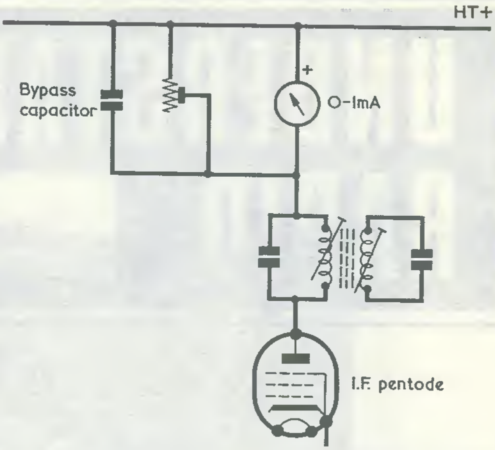

*Fig. 3. A simple example of a meter tuning indicator, in which the meter is inserted in series with the anode supply to an a.g.c. controlled i.f. pentode. The bypass capacitor offers a low reactance at intermediate frequency and could have a value of some 0·02μF.*

The fact that the double diode pentode has its cathode at chassis potential means that the load for its diode ($R_1$ in series with $R_2$ in Fig. 1) may also be returned to chassis. Signal detection follows standard practice and there is no voltage delay on the a.g.c. system.

The voltage amplifier triode of the triode pentode has its cathode connected to chassis. This employs grid current bias, which we have already discussed in recent articles. The output pentode has standard cathode bias.

The basic a.g.c. circuit of Fig. 1 has been employed in many low-cost commercially made a.m. valve receivers. A commonly encountered variation consists of using a series feed circuit for the signal frequency section of the frequency changer, the lower end of the first i.f. transformer secondary being returned to the bypass capacitor. (This version is similar to Fig. 3 in last month's article). The basic circuit may also be met in receivers incorporating the following "line-up": frequency changer, i.f. amplifier pentode, double diode triode and separate output pentode. In this instance, the signal and a.g.c. diode is transferred to the double diode triode instead of being in the double diode pentode.

The presence of contact potential in the a.g.c. diode has not been mentioned before whilst discussing a.g.c. systems, because its effect may usually be ignored. However, it should be taken into account in a carefully designed receiver using a single diode for signal detection and a.g.c., and having cathode bias for the controlled valves. In this case the contact potential should be allowed for when determining the cathode bias voltages, as it will be present in the absence of signal and may slightly affect the sensitivity of the receiver to very weak signals.

Experimentally minded readers may find it of interest to carry out the simple test shown in Fig. 2(*a*). Here, any diode of the type used for signal detection has its heater connected to a suitable supply, and a high resistance voltmeter is connected between anode and cathode. If the diode cathode is at emitting temperature, the voltmeter should give an indication of some 0·5 volts contact potential. The same results are given between the control grid and cathode of a triode or pentode valve, as shown in Fig. 2(*b*). The experiment of Fig. 2(*b*) will be most successful when the valve has a cathode capable of providing a high electron current, as occurs in an a.f. output valve.

## A.G.C. AND A.V.C.

Before concluding on a.g.c. systems two final points concerned with terminology, need to be mentioned.

The term "automatic gain control", or "a.g.c.", is the one commonly employed for describing the systems we have been examining. An earlier term for such systems was *automatic volume control*, or *a.v.c.* This last term is out-dated, but is occasionally encountered in references to sound receivers. The term "automatic gain control" is to be preferred because a.g.c. systems are also used in r.f. and i.f. amplifiers, such as those encountered in television receivers, which are not intended to produce an audio signal.

Another term commonly employed is *a.g.c. line*. This refers to the circuit line employed for carrying the a.g.c. voltage to the controlled stages, and is identified in Fig. 1.

## TUNING INDICATORS

It is a simple matter to add a *tuning indicator* to a valve a.m. superhet, the function of this indicator being to show when the tuning capacitor is in its optimum position for the reception of a signal. Such an indicator is of value in a receiver fitted with a.g.c. because it enables accurate tuning to be achieved even when, due to the a.g.c. action, the volume level from the loudspeaker for a single transmission remains virtually unaltered over a wide range of tuning adjustment.

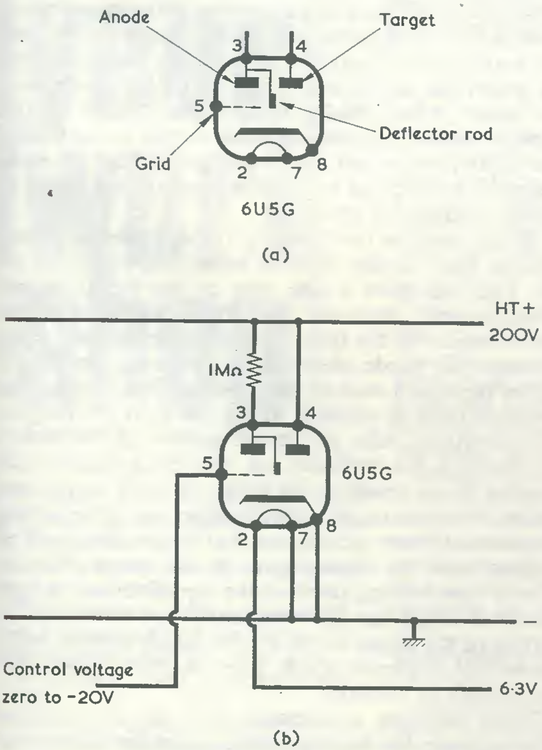

*Fig. 4 (a). Circuit symbol for the "Magic Eye" tuning indicator type 6U5G*
*(b). The 6U5G in a working circuit.*

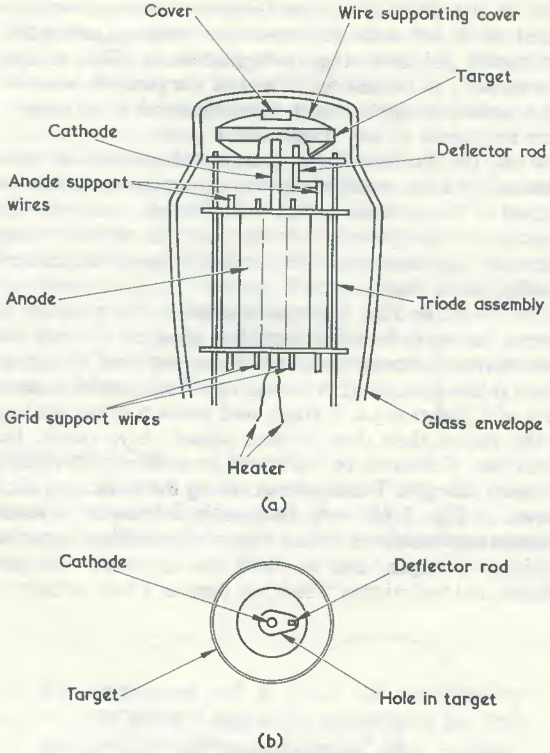

*Fig. 5 (a). A side view, showing the internal structure of the 6U5G.*
*(b). Looking down on the target with the cover of (a) removed. The surface shown here is coated with fluorescent material.*

There are two main types of tuning indicator. One consists basically of a meter, the deflection of whose needle indicates the accuracy of tuning. The other employs an *electron-ray tube* which presents a visible fluorescent display whose area varies according to the control voltage applied to it. The electron ray tube is assembled in an evacuated glass envelope in the same way as is a valve. Both types function by indicating in visual form the voltage across the a.g.c. diode load or across the signal detector diode load. It will be remembered that this voltage increases as the receiver is brought nearer the correct tuning point for a given signal. If the a.g.c. diode is fed from the anode of the last i.f. amplifier valve (instead of from the secondary of the last i.f. transformer following that anode) it is better for the tuning indicator to obtain its control voltage from the signal detector diode load, where the voltage will rise more sharply as the position of correct tuning is approached.

Fig. 3 shows a very simple form of tuning indicator incorporating a meter. This meter, which may have a full-scale deflection of, say, 1mA, is inserted in series with the anode supply to an i.f. amplifier pentode. It is assumed that the a.g.c. voltage in the associated receiver is obtained from a diode fed by the secondary of the last i.f. transformer, whereupon it will increase sharply as the receiver tuning is brought closer to its correct point. The preset variable resistor across the meter in Fig. 3 is adjusted so that, in the absence of signal input to the receiver, the meter reads full-scale deflection (i.e. with a 1mA meter, the needle points to the 1mA gradation). This reading corresponds to the anode current of the pentode when no a.g.c. voltage is applied to it, as would occur if the receiver were not tuned to any transmission.

When the receiver tuning is adjusted towards a transmission the a.g.c. voltage starts to rise, causing the anode current of the pentode to fall. This drop in anode current is indicated by the meter needle and the correct tuning point for the receiver corresponds to minimum current reading in the meter.

The meter in Fig. 3 not only enables the position of correct tuning to be found but also, after the receiver has been correctly tuned, indicates the *strength* of the signal which is being received. A strong signal causes the appearance of a higher a.g.c. voltage, and hence a lower reading in the meter, than does a weak signal. As a result, the meter can, if desired, be calibrated in units corresponding to signal strength. Tuning meters using the basic approach shown in Fig. 3 are very frequently employed in communications receivers, where they also provide a measure of signal strength, and we shall deal in detail with the circuits and techniques which are used in a later article.

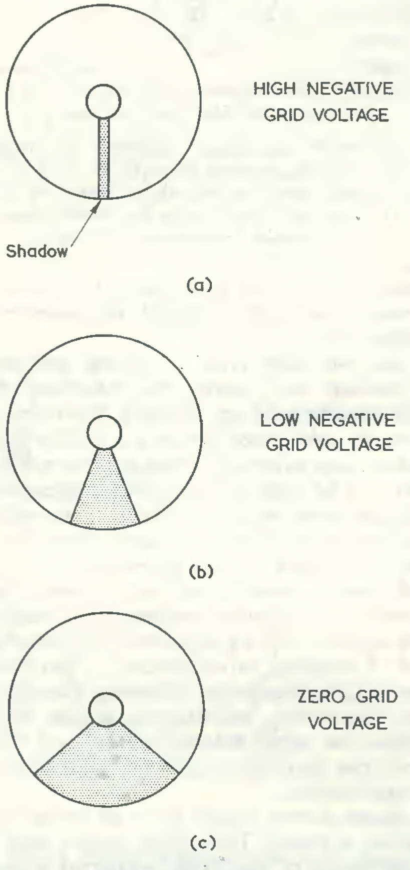

*Fig. 6 (a). Typical 6U5G display when the triode is near cut-off. All the area within the circle glows green with the exception of the shadow.*
*(b). The shadow widens as the grid becomes less negative.*
*(c). The shadow is at its widest when the grid has zero potential with respect to cathode.*

We turn next, this month, to tuning indicators which employ fluorescent displays, and we shall deal first with the type which is popularly known as the "Magic Eye". An early version of the "Magic Eye" is given by the valve type 6U5G and, since this represents what is virtually the simplest type of device available using "Magic Eye" principles, we shall use it for an introductory example. The 6U5G is fitted on an octal base, and it has approximately the same outside dimensions and shape as any octal-based valve in the "G" category.

A circuit symbol for the 6U5G is shown in Fig. 4(*a*), and it will be seen that this incorporates a triode with its familiar cathode, grid and anode. Connected internally to the anode is an electrode described as a "deflector rod." There is also a "target" (shown in the same way as an anode) which is in juxtaposition with the common cathode but without an intervening grid.

Fig. 4(*b*) illustrates the "Magic Eye" in an operating circuit. Here, the target connects direct to the h.t. positive supply line. The anode connects, via a 1MΩ resistor, to the h.t. positive supply line also. The cathode connects direct to chassis, whilst the grid connects to a varying control voltage which can range from zero potential to about 20 volts negative, both with respect to chassis.

The characteristics of the triode section in Fig. 4(*b*) are such that, for a grid voltage of approximately 20 volts negative of cathode, the triode is cut off and no anode current flows. Thus, no current passes through the 1MΩ resistor and both the anode and the deflector rod are at the same potential as the target. If, next, the negative voltage on the grid is gradually reduced, the triode will commence to pass anode current, causing a voltage to be dropped across the 1MΩ resistor. In consequence, the anode and deflector rod go negative of the target by that voltage. As the negative grid voltage continues to reduce the anode current increases, and so also does the voltage by which the anode and deflector rod are negative of the target. When, finally, the grid potential is equal to cathode potential, maximum anode current passes through the 1MΩ resistor and the anode and deflector rod are negative of the target by the maximim voltage which the device is capable of providing.

We can see how these varying voltages affect the visual "Magic Eye" display by next examining Figs. 5(*a*) and (*b*). Fig. 5(*a*) gives a side view of the 6U5G internal structure and illustrates the triode assembly in the lower section of the tube. The common cathode passes through the triode electrodes, continuing up until it passes through a hole in the lower surface of the target electrode (part of which is shown cut away for purposes of illustration). Also projecting up through the hole in the target is the deflector rod, this being mechanically coupled to the triode anode below. A small metal cover affixed above the target hides the upper end of the cathode from outside view and ensures that its red glow does not distract from the display given by the target. Fig. 5(*b*) gives a view looking down at the top of the target (with the cover which has just been mentioned removed). The surface of the target visible in Fig. 5(*b*) is covered with a fluorescent material which gives a green glow when bombarded by electrons.

When the tube is operated with the triode section drawing a very low anode current, so that the deflector rod is just slightly negative of the target, the target fluoresces over all its surface except for a very small area which is in the shadow of the deflector rod. See Fig. 6(*a*), which shows the target surface with the tube oriented such that the deflector rod is below the cathode. This fluorescence is due to electrons being emitted radially from the surface of the cathode. If the triode anode current is made to increase by causing its grid to become less negative, the deflector rod potential becomes more negative than that of the target whereupon it offers electrostatic repulsion to the electrons emitted from the cathode. As a result, these electrons do not pass as close to the rod as occurred previously, and the visible effect is that the angle of shadow widens, as in Fig. 6(*b*). When the triode anode current is at its maximum (as occurs when the grid is at the same potential as its cathode) the deflector rod is at its most negative with respect to the target and it offers greatest repulsion. The angle of shadow is then at its widest, as in Fig. 6(*c*).

Thus, the angle of shadow in the "Magic Eye" display varies according to the voltage on the triode grid. Working through the effects we have just discussed in reverse order, the angle of shadow is at its widest when the triode grid has the same potential as its cathode. If the grid is made to go negative of the cathode the angle of shadow narrows until, when the triode section is very near cut-off, the angle is at a minimum, as shown in Fig. 6(*a*).

A minor point not so far mentioned is that, if the triode grid is made more negative again, so that the triode becomes completely cut off, the angle of shadow disappears, and the fluorescent areas on either side give the effect of overlapping each other.

It will be apparent that the "Magic Eye" can give excellent results as a tuning indicator in a valve a.m. receiver since the only basic requirement is that its grid be coupled to either the signal diode load or the a.g.c. line. In the absence of signal the "Magic Eye" will then offer maximum angle of shadow. When a signal is being tuned in, its grid voltage will go negative, whereupon the angle of shadow becomes narrower. The position of correct tuning is indicated by the narrowest angle of shadow in the "Magic Eye".

## NEXT MONTH

In next month's article we shall deal with the practical circuits required for coupling the "Magic Eye" to the receiver signal diode or a.g.c. circuits, after which we shall examine other types of electron-ray tube indicator. ✱

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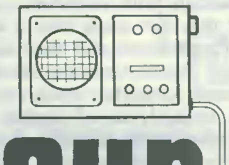
# In your work-shop



**Dick could never be accused of a lack of curiosity and, after a study of the spare service manuals in the Workshop, he is brim-full of questions. As usual, Smithy the Serviceman rises to the occasion, and he is able to satisfy his assistant's search for knowledge on a variety of matters, these ranging from electrolytic capacitor voltage ratings to fusible resistors.**

"WHAT is it," asked Dick, "that lies on the bottom of the sea and shivers?"

Irritably, Smithy crashed his soldering iron down on its rest.

"For goodness' sake," he snorted, "stop coming out with these nonsensical riddles of yours. All right, what is it?"

"A nervous wreck," replied Dick promptly.

"And that," pronounced Smithy, "is what *I'll* be if you keep on with those idiotic jokes of yours. That's about the fourth in the last hour. Haven't you got anything to do?"

"Not a great deal," replied Dick. "I've cleared up the final set that's in for repair and I'm just passing the last half-hour before packing-up time by looking through some of the service sheets we've got on file."

"Well, that should keep you occupied."

"It has," said Dick. "At the same time, though, I've bumped into one or two things in some of these circuits which have got me puzzled. I was wondering whether you might shortly have a bit of time spare yourself, so that you could explain them to me."

Smithy looked at his watch.

"That could be arranged," he conceded. "It so happens that I've very nearly finished the present job I'm working on. So, if you don't interrupt me any more, there's a good chance of my being free in about five minutes' time."

### ELECTROLYTIC CAPACITOR RATINGS

Dutifully, Dick remained silent whilst the Serviceman continued with his work.

"Ah, there we are," remarked Smithy with a satisfied grunt as he finally switched off the receiver he had been repairing. "And that's that!"

Eagerly, Dick sprang up and carried the receiver to the 'Repaired' rack.

"I must say," remarked Smithy, a little taken aback at Dick's unwonted helpfulness, "that was very civil of you."

"Think nothing of it," said Dick carelessly, as he returned to his bench. "Now, the first question I want to ask you concerns the voltage ratings of the h.t. electrolytic capacitors you get in valve radio and TV sets."

"Blimey," commented Smithy, taking his stool over to Dick's bench, "you don't waste much time, do you?"

"What I don't understand," continued Dick unabashed, "is why in most home-constructor valve designs it's usual to use h.t. electrolytics having a working voltage equal to the peak rectified voltage, whereas commercially-made sets have electrolytics with a much lower working voltage. Look at *this*, for instance."

Dick showed Smithy the circuit of an a.m./f.m. radio and prodded at the h.t. rectifier section. (Fig. 1).

"Now here," he said, "you've got a mains transformer secondary bashing out no less than 250 volts r.m.s. into a bridge metal rectifier. Before the valves warm up and start drawing current after

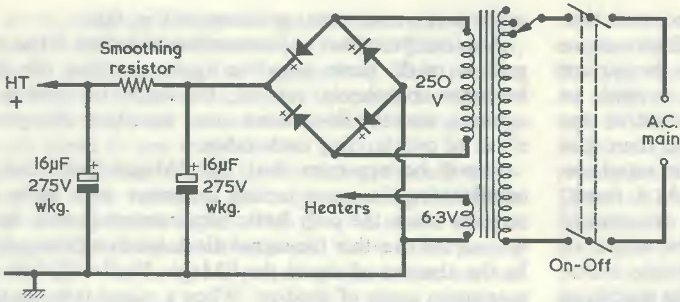


*Fig. 1. As is illustrated here, commercially manufactured valve equipment normally employs h.t. electrolytic capacitors having lower working voltages than would be employed in home-designed circuits. This apparent anomaly is explained by Smithy to his assistant.*

switching on, that rectifier, as I understand it, is going to cause the reservoir and smoothing electrolytics to charge up to the full peak value of the alternating voltage on the transformer secondary."

"Which is," put in Smithy helpfully, "250 times 1·4, or 350 volts."

"Exactly," returned Dick triumphantly. "Why is it, then, that the two electrolytics in this set have a working voltage rating of 275 volts only?"

Smithy chuckled.

"This is an instance," he remarked, "where the set manufacturer has the edge over the home-constructor."

"How come?".

"The set-maker," explained Smithy, "has access to information which is not so readily available to the constructor. To start off with, aluminium electrolytic capacitors of the class we're considering here have *surge* ratings in addition to their working voltage ratings, the surge rating usually being about 50 to 100 volts above the working voltage which is marked on the case. Such capacitors can withstand a short period of excess voltage across them immediately after switching on. But there's more to it than that."

"Is there?"

"Oh yes," said Smithy. "What I must point out next is that the leakage current in an aluminium electrolytic starts to rise very quickly when the voltage across its plates exceeds the working voltage. (Fig. 2). Most commercially manufactured valve radio and TV sets take advantage of this effect, and the increased leakage current in the h.t. reservoir and smoothing electrolytics actually serves the purpose of keeping the rectified h.t. voltage from rising to too high a level before the valves have warmed up."

"Gosh," said Dick impressed. "That's a bit dicey, isn't it?"

"Not when you have all the information applicable to the capacitors being used, and it tells you that they are capable of being operated in this manner," explained Smithy. "Now, if a commercially made valve receiver with a new type of h.t. circuit is to be launched, the circuit designer will first of all check through the capacitor maker's data to find the most economic capacitors suitable for the job. This will include checking surge ratings and the ability to pass extra leakage current. If necessary, he will also check directly with the capacitor maker's technical staff as well. After he has satisfied himself that all is well, he'll then specify suitable capacitors for the application, and these will almost certainly have a lower working voltage than the peak voltage to which they can be subjected."

"A home-constructor," remarked Dick, "couldn't possibly do all that."

"Not very easily," agreed Smithy. If a home-constructor is making up his own circuit design, and is using components bought over the counter or through the post, his best approach will be to play safe and employ reservoir and smoothing electrolytic capacitors whose working voltage is equal to the peak voltage they're liable to have applied to them. Which, in your example, is 350 volts. If he employed capacitors with a lower working voltage he could well be unlucky and find the ones he's using won't stand up to the surge conditions imposed on them."

"Fair enough," said Dick. "Incidentally, why did you keep referring to these electrolytics as aluminium electrolytics?"

"Did I?" replied Smithy. "It must have been a reflex action on my part, now that tantalum electrolytic capacitors are appearing on the scene so much these days. As you know, an ordinary common-or-garden electrolytic capacitor uses aluminium foil for the plates, the dielectric being given by an oxide film which is formed on the surface of the foil connected to the positive terminal of the capacitor. With tantalum electrolytics, the plates are made of the metal tantalum."

"Are there any advantages with tantalum capacitors?"

"Definitely," replied Smithy. "For instance, the properties of the oxide film formed on a tantalum foil, together with those of the electrolyte employed, are such that leakage current is lower than with aluminium electrolytics. Another advantage with tantalum capacitors is that they can work over a wider range of temperatures and their useful life is longer. Again, tantalum electrolytics can be made somewhat smaller than aluminium electrolytics of similar value. On the other hand, tantalum capacitors are not usually encountered with working voltages higher than about 150. Also, since tantalum is a more expensive metal than aluminium and, being much harder is not so easy to roll out into foil, tantalum electrolytic capacitors tend to be more expensive than their aluminium counterparts."

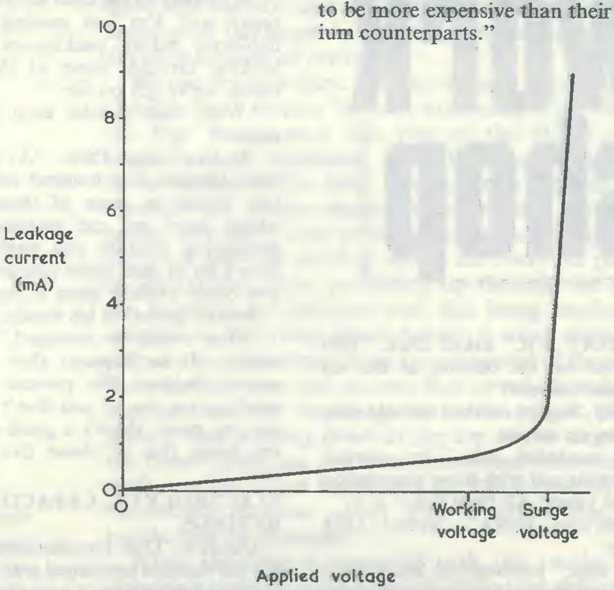


*Fig. 2. Aluminium electrolytic capacitors with working voltages of around 200 or more exhibit leakage current/voltage characteristics similar to that shown here.*

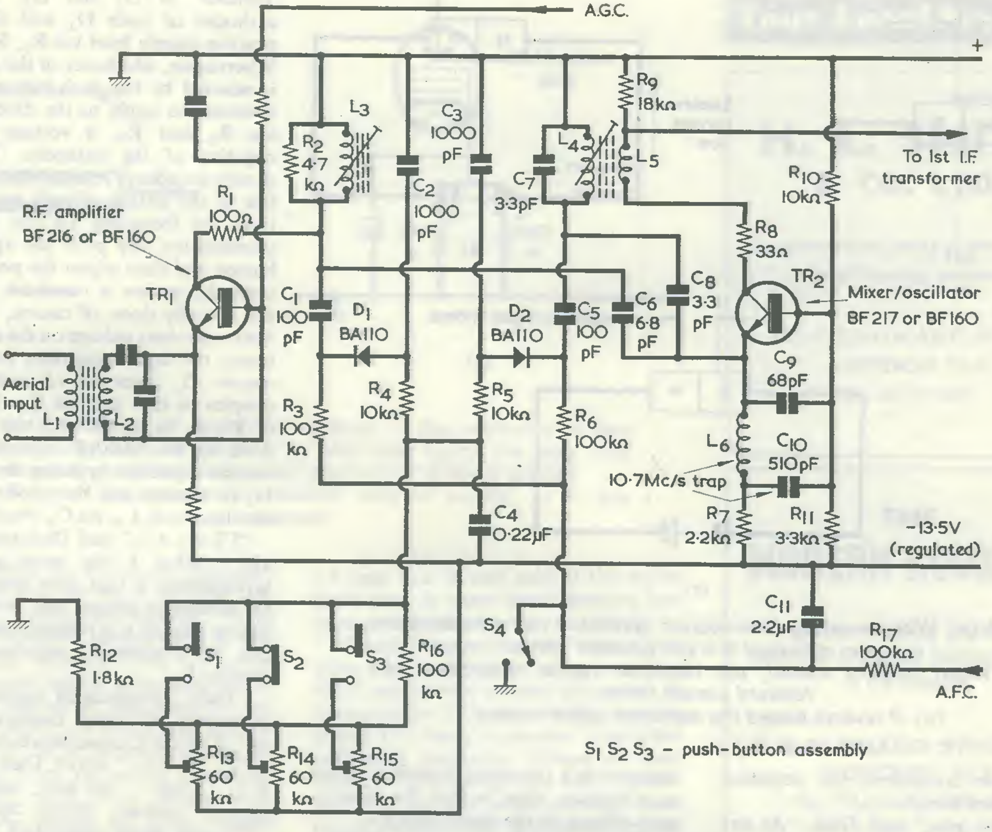


*Fig. 3. Slightly simplified circuit illustrating the variable capacitance diode tuning system employed in the H.M.V. 'Stereomaster' Model 2328. (See the accompanying Editor's Note).*

## VARIABLE CAPACITANCE DIODES

"I see," said Dick, turning to another service sheet. "Well, that seems to clear up the electrolytic query I raised. Here's something else that's been puzzling me. It's an f.m. receiver front-end circuit which has no visible means of tuning whatsoever!"

Dick handed Smithy a circuit for a stereo radiogram, and indicated the front-end section in question. (Fig. 3).

"What's your trouble here?" asked Smithy, glancing briefly at the circuit. "So far as I can see it's perfectly obvious how the tuning is being carried out."

"It may be obvious to you," retorted Dick irritably, "but it jolly well isn't to me. The only variables I can see in the r.f. and oscillator tuned circuits are the dust cores for the coils, and even those are shown as being preset. There isn't a variable capacitor to be seen, mate!"

"There *are* three potentiometers, though."

"Potentiometers? Whoever heard of adjusting tuned circuits with a pot?"

"Well, that's just what's being done here," replied Smithy decisively, "and a very nice and simple circuit it is too. What you have omitted to notice are the two diodes $D_1$ and $D_2$. These are variable capacitance diodes and their function is to apply a capacitance to the r.f. and oscillator tuned circuits which varies according to the reverse voltage that's fed to them by the pots."

"Variable capacitance diodes, eh," said Dick musingly. "I seem to have heard something about them at some time in the past."

"They've been knocking around for a good many years now," said Smithy. "However, it's only recently that they seem to be finding their way into domestic electronic equipment made in this country."

"How do they work?"

"They take advantage of a property which is evident in practically all semiconductor junction diodes," said Smithy. "This property being that, if the diode is reverse biased, the capacitance across the junction decreases as the reverse bias increases. The theoretical explanation is fairly simple and is quite easy to follow if you're well enough up in diode and transistor theory to know that the negative charge carriers in a semiconductor material are free electrons, and that the positive charge carriers are holes."

"A hole," put in Dick, "being actually a convenient method of describing the absence of an electron?"

"Precisely," confirmed Smithy. "And I hardly need to remind you that the semiconductor material is doped by adding very small quantities of impurities so that it either has free electrons wandering around in it, or it has free holes. If the impurity causes the appearance of free electrons you then have an n-type semiconductor and if it causes the appearance of free holes you have a p-type semiconductor. Now, when a p-n junction diode is formed, some of the electrons on the n side diffuse across the junction into the p side and some of the holes in the p side diffuse across the junction into the n side. This process is an almost instantaneous one and it stops when a state of equilibrium is reached. There is then a quantity of electrons on the p side of the junction and another quantity of holes on the n side with no further diffusion from one side to the other taking place. At the junction itself, therefore, there are no free electrons or holes. This is, in consequence, described as the 'depletion region', and it offers a very high resistance. You could also say that it resembles the dielectric of a capacitor, the two plates of which are the pieces of semiconductor material on either side.

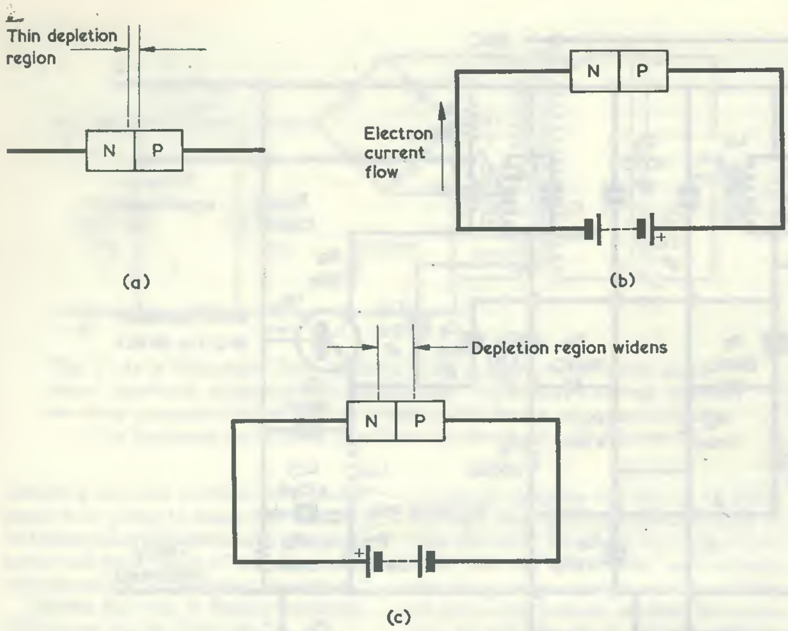


*Fig. 4 (a). With no external connection applied, a very thin depletion region is formed in a p-n junction diode.*
*(b). When forward biased, the depletion region disappears and forward current flows.*
*(c). If reverse biased the depletion region widens.*

Under these conditions, the depletion region is very thin."

"I'm with you," said Dick. "At any rate, up to now I am!"

"Good show," replied Smithy, pulling Dick's note-pad towards him and making a few sketches. "Well, now, let's draw the diode with nothing connected to it, giving us the very thin depletion region where there are no free charge carriers. (Fig. 4 (*a*)). Let's next put a forward bias on the diode, so as to make it pass forward current, by connecting a battery to it with battery negative to the n side. (Fig. 4 (*b*)). The depletion region at once disappears, electrons from the n side pass over to the p side and holes from the p side pass over to the n side. Really, of course, the forward current is *all* electrons, with new electrons coming from the negative terminal of the battery. If, next, we apply a reverse bias, quite a different thing happens. (Fig. 4 (*c*)). There is obviously, no forward current. Instead the electrons which are left in the n side are attracted towards the positive terminal of the battery, and the holes which are left in the p side are attracted towards the negative terminal of the battery; and the final result is that the depletion region widens. As is to be expected, the amount by which it widens varies according to the magnitude of the reverse voltage."

"I can see how this is going to work out," Dick broke in. "The widening of the depletion region due to reverse bias is the same as the widening of the dielectric in a two-plate capacitor. What must happen, then, is that the capacitance offered by the diode reduces."

"That's right," concurred Smithy, "and that's exactly what happens in a variable capacitance diode. As reverse voltage increases the capacitance offered by the diode reduces. As I mentioned earlier, this effect is present with virtually all semiconductor junction diodes, and variable capacitance diodes are merely diodes which have been specially designed to exploit the effect to the full. Having got that little lot sorted out, let's go back to the f.m. front-end circuit you were so puzzled about. Now in this particular case the tuning of the front-end is not continuously variable by means of a front panel knob as you get on an ordinary receiver. Instead, there are three push-buttons which select one of the three pots, $R_{13}$, $R_{14}$ or $R_{15}$. These are set up individually for Radio 2, Radio 3 and Radio 4. You'll notice that the aerial input transformer, $L_1$ $L_2$, is broadly pre-tuned to the centre of the f.m. band, this being common practice with all f.m. front-end circuits. Assume for the time being that $S_4$ is closed, whereupon the lower ends of $R_3$ and $R_6$ are at chassis potential. In this circuit, incidentally, the chassis connection is to the upper positive supply line, and not to the lower negative supply line."

Smithy made a further sketch. (Fig. 5).

"I've just drawn this," he remarked, "so that you won't get confused when I start talking about the 'anode' and the 'cathode' of $D_1$ and $D_2$. Now, the cathodes of both $D_1$ and $D_2$ are at positive supply level via $R_3$, $R_6$ and $S_4$. Whereupon, whichever of the three pots is selected by the push-button switches is bound to apply to the diode anodes, via $R_4$ and $R_5$, a voltage which is negative of the cathodes. Thus, the diodes are always reverse biased, regardless of the setting of each pot. To pre-tune the front-end to any particular transmission you press the appropriate button and then adjust the pot it selects until the station is tuned in. What the pot actually does, of course, is to vary the reverse bias voltage on the diodes and hence, the capacitance they put into the circuit. $D_1$ tunes the r.f. coil, $L_3$, and couples to that coil via $C_1$. The anode of $D_1$ is, as you'll see, tied down to deck by the 1,000pF capacitor $C_2$. A similar capacitor bypasses the anode of $D_2$ to chassis, and this diode tunes the oscillator coil, $L_4$, via $C_5$. Neat, isn't it?"

"I'll say it is," said Dick enthusiastically. "What I like most about the arrangement is that both tuned circuits are effectively ganged and that the only tuning control is a potentiometer which can be positioned *anywhere* in the receiver."

"That," pronounced Smithy, "is an important advantage conferred by the use of variable capacitance diodes."

"Won't they," asked Dick suddenly, as a thought struck him, "damp down the tuned circuits they're coupled to?"

"These ones shouldn't," replied Smithy. "They're silicon diodes and will have a very high back resistance. Earlier variable capacitance diodes were germanium types and they might well have had a damping effect on any tuned circuit they were coupled to."

"What sort of capacitance shift can you get with these diodes?"

"With the type we have in this circuit," said Smithy, "I should imagine you'd get a capacitance swing from minimum to maximum of some 20 to 30pF or so. However, this is quite a low variation. Some silicon variable capacitance diodes have been produced which offer maximum capacitance up to 250pF or more."

"Just the job," said Dick, "for tuning a transistor radio!"

"True enough," replied Smithy. "Provided, that is that the diode offers a really low minimum capacitance as well. Personally I wouldn't be at all surprised to see variable capacitance diodes used for tuning broadcast band receivers in the fairly near future."

"Just a minute, Smithy," said Dick. "What happens in this f.m. front-end circuit of ours if we open switch $S_4$?"

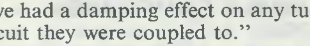


*Fig. 5. Illustrating the 'anode' and 'cathode' of a semiconductor diode.*

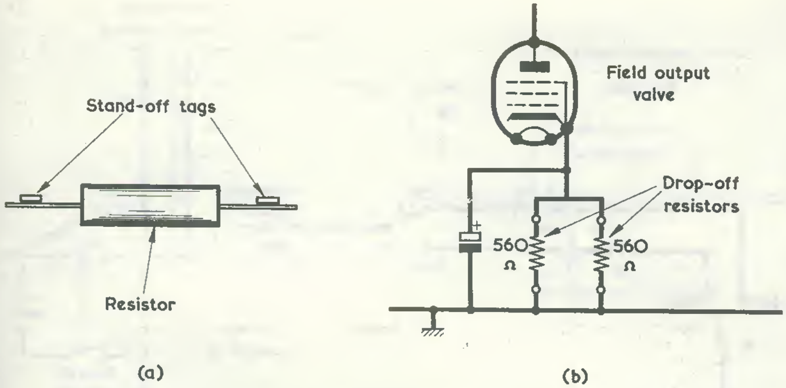


*Fig. 6 (a). A drop-off resistor is soldered to the underside of two stand-off tags without twisting its lead-outs round the tags. The diagram shows the resistor and tags before solder is applied. (b). Drop-off resistors are sometimes used in parallel, as in this example.*

"You allow the automatic frequency control, or a.f.c. for short, to come into operation," explained Smithy. "This particular receiver incorporates a balanced ratio detector with an audio take-off point which goes negative of chassis if the set is mis-tuned to one side of the signal and which goes positive of chassis if the set is mis-tuned to the other side. When the tuning is spot-on, the take-off point is at chassis level. Opening $S_2$ causes an a.f.c. voltage from this take-off point to be applied to the cathodes of $D_1$ and $D_2$ via $R_3$ and $R_6$, whereupon it corrects any slight mis-tuning which might otherwise creep in. The pots must, of course, be initially set up with $S_4$ closed, since their correct positions would otherwise be masked by the a.f.c. system."

## DROP-OFF RESISTORS

"Oh well," said Dick, "that's another little problem of mine sorted out!"

He turned to another service manual then stopped for a moment as a thought occurred to him.

"Tell me, Smithy," he asked, "what's yellow with sharp teeth?"

The Serviceman sighed.

"You tell me," he said wearily. "What *is* yellow with sharp teeth?"

"Shark-infested custard!"

"I don't," said Smithy heavily, "wish to know that. Kindly leave the Workshop."

"I will in a few minutes," grinned Dick, "but only after you've cleared up another query for me."

Smithy assumed an expression of complete resignation.

"Fire away."

"Why is it," asked Dick, "that TV set-makers don't put a few more fuses in their sets? There are a terrific amount of different stages in a TV set, all of which draw current, and yet all I've found in the circuits I've been looking through here is the regulation 1·25 or 1·5 amp fuse in one side of the mains input plus, in some cases, another fuse immediately after the h.t. rectifier."

"I think," replied Smithy, "that you're being a bit unfair to the set-makers here We'll restrict this present discussion to monochrome TV's, incidentally, because colour TV's have, in general, quite a few additional protective devices in their circuits. This having been said, I'll also agree that up until recent years the main run of monochrome television receivers did have simple fusing arrangements of the type you've just described. But what you must next consider is the important basic fact that the provision of more fuses would not really offer the sort of protection you're thinking about. Even the mains and h.t. fuses you've already mentioned can't provide a *great* degree of protection if a fault is such that the overall mains or h.t. current increases by a small margin only. This is because the fuses must also be capable of withstanding the current surge which results if the set is switched off then switched on again whilst still warmed up and capable of drawing full current. Under these conditions, the best the set-maker can do is to fit fuses which will blow with really *heavy* overloads, as are given by such things as shorts to chassis on the main h.t. line or shorts in the h.t. rectifier."

"Perhaps I *was* being a bit unfair with my comments," admitted Dick.

"You were also being unfair," continued Smithy, "for another reason. This being that, in many of the more recent monochrome models, a number of additional protection circuits *are* provided. For instance, some receivers have drop-off resistors."

"Drop-off resistors?"

"That's right," confirmed Smithy. "These have been in use in the Philips group range of TV sets for quite some years now. You'd have noticed them

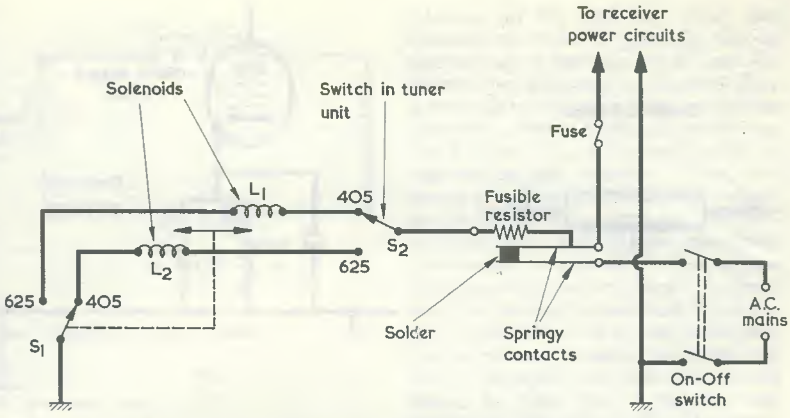


*Fig. 7. A fusible resistor in series with a 405/625 line system switching circuit. Power is cut off to the whole receiver if the fusible resistor contacts open.*

if you'd kept your eyes open."

"What do they look like?"

"A drop-off resistor," said Smithy in reply, "consists of a standard 1 watt resistor inserted in the anode or cathode circuit of a valve which normally draws a fairly high current and which can, under fault conditions, draw a much larger current. Each drop-off resistor is soldered, with its lead-outs kept straight, to the under-surface of two stand-off tags. The result is that if it overheats because too much current passes through it the solder melts and the resistor simply drops off the tags, thereby breaking the circuit." (Fig. 6 (*a*)).

"Blow me," said Dick. "That's a neat scheme."

"It is, rather," replied Smithy. Apart from its simplicity, it has the advantage that the drop-off resistor can frequently provide the circuit resistance needed by the stage it protects, whereupon it gives overload protection at virtually negligible extra cost. If the normal dissipation would be too great for a single 1 watt resistor to handle, two in parallel can be used. A typical instance occurs in field output stages where you may find two 560Ω resistors in parallel in the cathode circuit. (Fig. 6 (*b*)). These resistors provide cathode bias, and they're mounted side by side on the same stand-off tags. Should there be excessive current in the resistors one of these will drop off first. It will soon be followed by the other because that will then have to dissipate even greater heat."

"What other stages are normally protected by drop-off resistors?"

"The video output stage," replied Smithy, "and the audio output stage."

"Are the resistors soldered up with low melting-point solder?"

"Oh no," said Smithy. "Ordinary 60/40 solder is used. This is the standard stuff you employ in wiring, and it goes liquid at 188°C. There are other advantages to this drop-off resistor idea I haven't mentioned yet. One of these is that the resistor isn't able to burn up over a long period and thereby scorch the printed circuit board. Again, it offers a lot of help to the service engineer. If you take the back off a set and find that a drop-off resistor has fallen away from its tags, you know exactly which stage is giving trouble.

"This drop-off resistor business," said Dick enthusiatically, "is one that could be exploited very easily by the home-constructor."

"Oh, definitely," confirmed Smithy. "But don't forget that it's only useful in equipment which is always operated upright, as is a TV set. The resistors used in the Philips sets, incidentally, are 1 watt components type BTA made by Dubilier."

"Are there any other protection devices in the more recent TV sets?"

"There are fusible resistors," replied Smithy. "These are devices which consist essentially of a 3 watt resistor having a value between some 10 and 100Ω according to application. Mechanically coupled to the resistor are two springy contacts which are held together at their tips by a solder joint. If the resistor becomes too hot due to excessive current flowing through it, the solder joint melts and the contacts open out and break the circuit. They can later be re-soldered together again, using ordinary 60/40 solder, after the fault which caused the overload has been cleared."

"Where do these fusible resistors appear?"

"In series with the main h.t. supply to the set," said Smithy. "And their main advantage is that they can stand switch-on surge currents without breaking the circuit. An excessive current which is continually maintained will, on the other hand, soon cause them to open up. They are also employed for protecting solenoid-actuated 405/625 line switching systems."

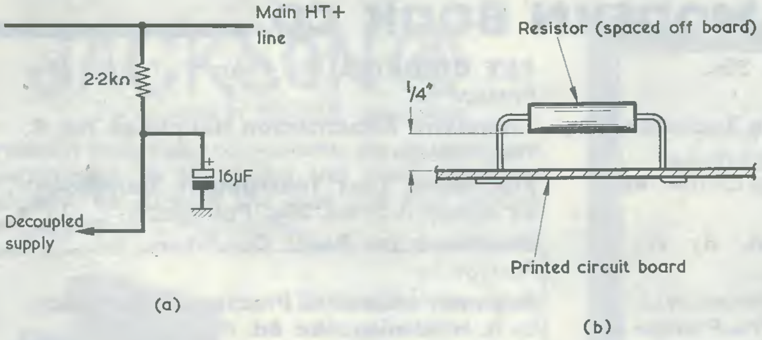


*Fig. 8 (a). A typical h.t. decoupling circuit in a television receiver. If the electrolytic capacitor breaks down, the 2·2kΩ resistor acts as a fuse by burning out.*
*(b). The resistor is spaced away from the board to avoid scorching its surface.*

"Why should those need protection?"

"In case they jam," replied Smithy, pulling Dick's note-pad towards him again. "A solenoid system switch works like this. (Fig. 7). The switch itself consists of the familiar long insulated bar extending over the length of the board, and which has all the i.f., video and line time-base switching contacts coupled to it. In this case, it also has the changeover switching contacts which I've marked here as $S_1$. $S_2$ is in the tuner unit. Let's assume that the system is in the 405 line position, as I've shown it here with the tuner unit selecting a 405 line channel. If the tuner is swung over to u.h.f., switch $S_2$ changes over to its other contact, energising solenoid $L_2$. This pulls the system switch bar over to the 625 position, whereupon its own contacts $S_1$ change over and break the circuit again. Thus, there is a momentary current in the solenoid which ceases as soon as the switching operation is completed. This operation is repeated in the opposite direction when the tuner unit is returned to a 405 line channel, thereby causing $S_2$ to take up its original position and energise $L_1$. The supply for the solenoids is taken from the a.c. mains directly after the receiver on-off switch. As you can imagine, should the switch jam mid-way, the circuit could draw a very heavy current if the fusible resistor were not also included to protect it."

## SAFETY RESISTORS

"There seems," remarked Dick, "to be quite a few safety measures I hadn't known about in these TV sets."

"I'll tell you about another one," said Smithy, "which consists quite simply of using a resistor as a fuse. This is a good approach for cases where there would be, relatively, a very large increase in current in the event of failure as could occur, for instance, when the resistor is in a decoupling circuit feeding a bypass electrolytic. Like this. (Fig. 8 (*a*)). If the electrolytic broke down, there would be an exceptionally high increase in current, whereupon the resistor would just burn out. As you can see, the resistor also acts as a fuse, and the usual practice is to space it off the board by about a quarter of an inch so that it won't scorch the board surface when it burns out." (Fig. 8 (*b*)).

"Blimey," said Dick. "You can't get much simpler than that!"

"You can't, indeed," replied Smithy, with an air of finality. "Do you know, Dick, we've gone through a complete circle this afternoon. We started with electrolytics and we're finishing with electrolytics! Anyway, it's well after packing-up time and I'm now off home, mate."

With which words, the Serviceman resolutely donned his raincoat and strode off into the night, leaving his protesting assistant to switch off and lock up.

As he drove home, Smithy mused contentedly over the events of the day. He snorted with momentary irritation, however, at the memory of Dick's succession of jokes in what should properly have been a serious and soberly technical atmosphere. Shark-infested custard, indeed!

## EDITOR'S NOTE

The front-end circuit shown in Fig. 3 is a slightly simplified version of that given in the H.M.V. 'Stereomaster' v.h.f. stereo radiogram model 2328. $S_4$, shown in the diagram as a normal switch, is a press-button switch in the radiogram. Similar circuits, some with slightly different component values, appear in other recent H.M.V. stereograms. The circuit of Fig. 7 is used in the Thorn 950 series of television receivers—*Editor*.

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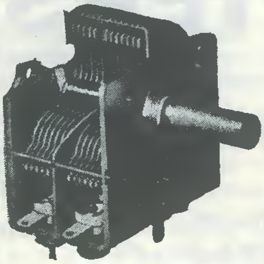

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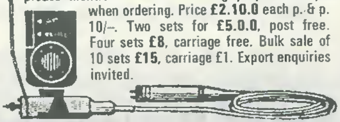

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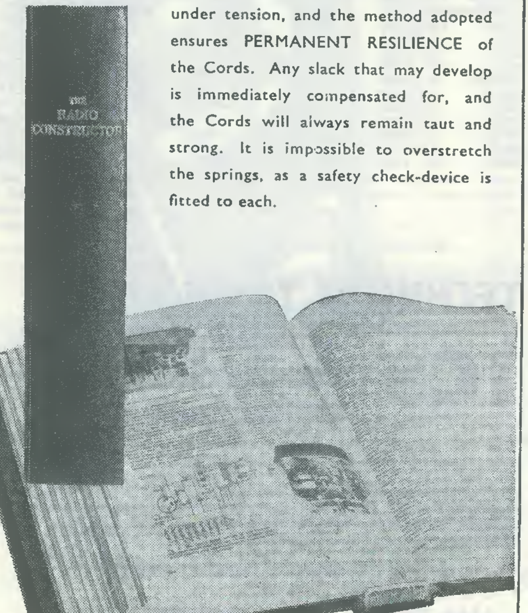

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*continued from page 542*

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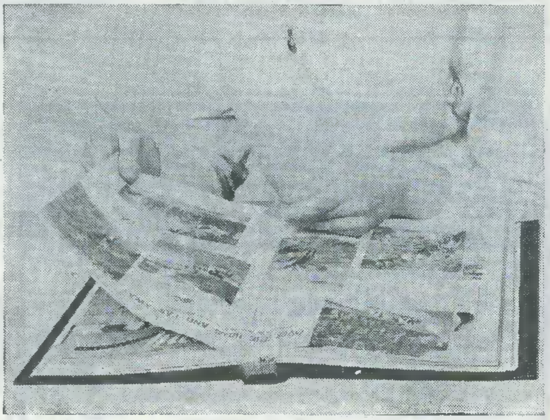

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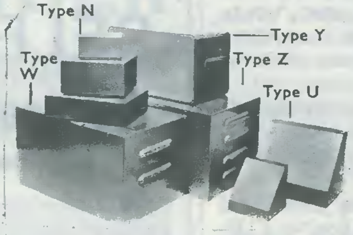

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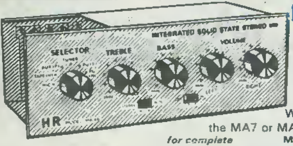

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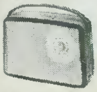

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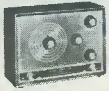

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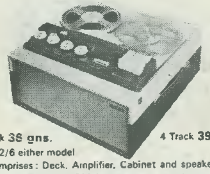

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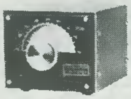

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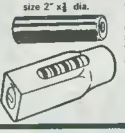

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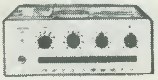

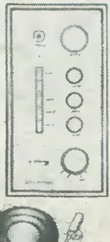

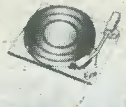

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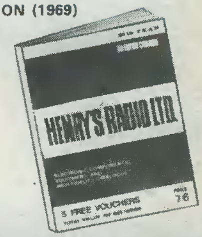

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