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Designing a Multi-Range Meter, by R. K. Vinycombe, B.Sc.

NOTICES
THE EDITOR invites original contributions on construction of radio subjects. All material used will be paid for. Articles should preferably be typewritten, and photographs should be clear and sharp. Diagrams need not be large or perfectly drawn, as our draughtsmen will redraw in most cases, but all relevant information should be included.
All Mss must be accompanied by a stamped addressed envelope for reply or return. Each item must bear the sender's name and address.
TRADE NEWS. Manufacturers, publishers, etc., are invited to submit samples or information of new products for review in this section.
ALL CORRESPONDENCE should be addressed to THE RADIO CONSTRUCTOR, 57 Maida Vale, London W.9 Telephone CUN 6518.
SUGGESTED CIRCUITS FOR THE EXPERIMENTER

The circuits presented in this series have been designed by G. A. FRENCH specially for the enthusiast who needs only the circuit and essential relevant data.

No. 39: Obtaining AF Gain without Hum

Obtaining high levels of AF amplification without introducing hum has been a problem which has always given trouble to designers of AF amplifiers. Hum pick-up raises difficulties not only in normal audio amplifiers but also, and perhaps to a higher degree, in more specialised high-fidelity equipment designed for operation over a wide frequency spectrum. In both cases, the eradication of hum necessitates a considerable amount of care in design, particular attention being paid to the layout of chassis earthing points, to the decoupling of supply circuits, and to the stress of connecting leads.

The part of an amplifier most susceptible to extraneous pick-up is obviously the first stage; and it is at this point that the most effective precautions have to be taken to prevent hum. Whilst it is possible to almost completely remove ripple from HT and to prevent inductive and electrostatic pick-up by means of suitable screening and one-point chassis connections, the question of unwanted couplings from the heater supply still remains. Indeed, when taken to its ultimate point, the only obstacle in the way of completely hum-free operation lies in the necessity of supplying 50-cycle AC to the heater of the first valve.

Supply at RF

This month's circuit shows an entirely new and, to the best of the writer's knowledge, hitherto unpublished method of feeding the heater of the first valve of an AF amplifier. Owing to recent development work by a manufacturer, this form of supply is now available to the home-constructor. It is capable of removing hum completely for all audio applications.

The circuit of the arrangement used is shown in Fig. 1. In this diagram, V1 is an RF oscillator, the tuned circuit for which is supplied by the winding L1 of the step-down RF transformer and the capacitor C2. The secondary winding, L2, on the transformer is connected to the heater of a second valve, V2. The RF voltage developed across L2 and applied to the heater is identical to the 6.3 volts given by conventional AC circuits.

V2 may be the first valve of an amplifier, whereupon it becomes completely free from hum pick-up for the obvious reason that its heater is supplied at a radio frequency.

Practical Considerations

It will be seen that the circuit is extremely simple to build up into practical form and that, apart from the self-demonstrable lack of hum, it has several other considerable advantages.

To begin with, owing to the low impedance at which the RF voltage is taken from the transformer, it is possible to add capacitance to as high a value as 1,000pF across the heater leads without materially affecting the voltage applied to the valve. This allows the heater supply to be carried by any desired type of wiring, including twin screened wire or conventional twisted pair.

Secondly, as the frequency at which the RF transformer oscillates may be made very much higher than the highest audio frequency to be handled by the amplifier, any RF pick-up by the first valve from its heater pins may be neutralised by a simple decoupling circuit, if this is needed at all. As the most probable source of pick-up is liable to be given by the self-capacitance existing between grid and heater pins of the valve itself, this may be ignored in most instances, as sufficient attenuation to RF should exist in the remainder of the amplifier. Alternatively, a simple bypass circuit consisting of a small RF choke and capacitor may be connected in the anode circuit. It will be remembered that the cathode of the first valve will be automatically decoupled to chassis by means of its bias capacitor.

The possibility of RF pick-up in the first stage may be even further reduced by connecting two balancing capacitors across the heater supply, as shown in Fig. 2. If one of these were made a trimmer, the RF could be "balanced out" completely; but it is doubtful if such an arrangement would be needed in most practical applications.

A third advantage is given by the fact that a range of negative bias voltages is immediately made available by tapping into the grid leak, R3, of the oscillator V1. This point has already been dealt with in Suggested Circuits No. 32, published in the August 1953, issue.

Further Points

The only disadvantage of the circuit lies in the fact that an extra valve is needed to drive the RF transformer. In normal amplifier design this is by no means a great problem, as the advantages conferred by a hum-free heater supply heavily outweigh the small extra cost involved. As a case in point, it may even be possible, by means of a reflex-type circuit, to have an output valve perform the secondary function of RF oscillator without detracting from its AF performance! Another suggested scheme would consist of having a single valve perform the dual roles of bias and heater generator in a tape recorder.

The design of a coil capable of acting as an RF transformer in this way is not easy, and great care is needed to prevent losses. It is possible, however, to heat a 6.3V 0.3A valve by means of a driver valve taking only 15mA from a 200V HT line. The efficiency of the RF transformer in such a case is quite high.

On the other hand, the choice of the driver valve, itself, presents hardly any difficulty at all. It is best, in an application of this type, to use a valve capable of handling two or three watts and to keep it slightly underrun. A 6H6, for instance, would be an excellent choice, and would have the advantage of requiring a heater current of 0.45A only.
ruder steering is given by varying the "space-mark" relationship of a multivibrator.

In the second part of the booklet, a more complicated arrangement is employed using pulse modulation. This method is based on the fact that a considerable number of valves are used in both transmitter and receiver, this method of modulation is one which, with modifications, may be of considerable interest to the amateur. A.H. Bruinsma gives full circuit diagrams, with values, of a system capable of handling eight pulses on one carrier. Although only one of the channels in his own particular application carries audio frequency in the form of speech and music, there is no reason why the other seven could not do so as well. As is to be expected, the total bandwidth is wide, it being about 2 Mc/s. This bandwidth could easily be reduced, nevertheless, by increasing the number of pulse channels, or by increasing the individual pulse times. Pulse repetition frequency, however, must be at least twice the highest audio frequency carried. His receiver is also of considerable interest, as he has obtained mains valve performance from battery-type valves. (The Philips valves mentioned in the booklet are, of course, available, under the same type-numbers, in Mullard.)

Acknowledgments

As mentioned above, this method of valve heating is now available to the home-constructor. The writer is indebted to Allen Components Ltd., the manufacturers of the RF heater transformer, for permission to publish advance information on their product, and also for allowing him to make suggestions which may enhance its usefulness to the amateur. (The Allen RF transformer had suited to the home-constructor is marketed under the type number RF 507.)
pleasure there must be in constructing some of those impressive and fearsome-looking machines; armed always with the knowledge that they would never be called upon to use. And yet, how far short of the ideal that they would never be called upon to use. However, it must have had some purpose, because its dial lights always came on whenever the engine started.

There was also a control unit for an SCR269 Radio Compass. Although this was unissued, I still waited with bated breath for it to be used for compass bearings. However, the director of the film must, very wisely, have realised that such bearings would be a little difficult to obtain below the surface; for this instrument was also not brought into use.

Now, I am not seeking to condemn science-fiction, nor to condemn science-fiction films, of which many are very good entertainment indeed. But I do dislike this secondary sort of film where the audience is pre-judged as having a level of intelligence which is slightly sub-moronic. The proportion of the cinema-going population which is versed in radio is nowadays quite high, and ridiculous shortcomings in presentation such as those I have just described will only add more people to the crowds who do not nowadays visit the cinema.

Tool Review

There are a fair number of tools on the market these days which are applicable mainly to the instrument, electrical and electronic trades. These are what are best described as “specialist” tools and consist of such things as wire-strippers, contact-cleaners, and so on. Many of these tools are relatively expensive; quite a few lying in the region between £2 and £5. Some of these tools are not easy to obtain in the smaller towns. Others, especially those which employ new and unfamiliar designs, are sometimes not heard of by the average technician until they have been on the market for several years.

When a group of tradesmen gather to talk “shop,” one very often finds that the subject of these specialised tools crops up, and it is surprising to find how many of the lesser-known types of tool are mentioned or described only with knowledge gained by hearsay. If a tool is capable of saving a tradesman time, it also saves him money. The decision of whether the initial cost of a specialised tool will prove a worthy investment rests, therefore, with the tradesman. Unfortunately, however, due to lack of immediate knowledge which I have just mentioned, the tradesman very often finds it difficult to make a choice.

I have decided, therefore, to start a series of specialist tool reviews in this column. These reviews will deal only with tools applicable to the radio trade and will occupy a small amount of space every three or four months. Such common tools as nippers, wiring pliers, etc., unless they be of strikingly new design, will not, of course, be included.

In the reviews I will quote the manufacturer’s address, the price, and the results claimed. Whenever possible, I shall check samples to see whether they meet the specification. It will be impossible for me to do more than check the immediate possibilities of any particular tool. If a manufacturer states, for instance, that a tool is capable of 10,000 operations, I shall quote the figure but will not be able to verify it.

On the other hand, if any tool does not appear to me to be suitable for the work it is claimed to do I shall not include it in the review.

I would be very grateful for the help of readers in this matter, especially welcoming any suggestions for tools to be included. I feel certain that, given sufficient cooperation, this series will prove of great value, not only to the amateur but, equally, to the professional engineer as well.
supersonic or spurious frequencies creating positive feedback. This type of instability is very real where pentode valves are so used. With a carefully designed preamplifier of this type employing, say, 10% NFB and 30% NFB, a 15% of bass lift, the nominal gain of 150 will drop to approximately 100, which of course is adequate for many orthodox requirements.

High Gain Phenomena

Good screening will, of course, diminish possibility of instability by providing capacitative paths to earth for the unwanted frequencies. This does not remove the cause of the trouble and does not improve the response curve of the preamplifier stage, and the author prefers the preventative rather than the curative method. The greater the gain the more pronounced this form of instability becomes, and in employing screening unduly a further loss in potential gain occurs. Thermal agitation noise is also greatly amplified in a simple high gain valve stage, which under near-maximum gain conditions, i.e. highest sensitivity, becomes prone to serious hum pick-up also.

The obvious approach to the over-all problem is the use of two medium gain stages employing triode valves, which are nowhere near so prone to third harmonic and spurious frequency generation. For greater gain and stability can in this way be obtained, although such a unit would be larger and more expensive than that of Fig. 1. It is with these foregoing considerations in mind that the author advocates the use of a double triode valve of the 6N7, 6S7, 6SL7, type. These may be obtained as small metal cased valves, which with screened grid leads should provide all the screening necessary.

Double-Triode Preamplifier

Fig. 2 depicts a circuit employing a metalised 6N7 which gives a number of marked advantages over the conventional preamplifier. Each stage has a gain of over 26, thus eliminating some of the preamplifier noise just discussed. The over-all gain is well over 700 without negative feedback and is more than sufficient for any requirement. Not many more components than in Fig. 1 are employed, and its physical dimensions can remain the same.

A very high degree of NFB is permissible, as spurious frequencies are virtually absent, and a great improvement of the over-all response curve may be effected at the expense of surplus gain. The NFB incorporated consists of a single resistor between the two signal grids, which should be wired directly across the valve holder. Its value will depend upon that percentage of feedback \( \beta \) required. The usual 5 to 15\% feedback may here be increased to 25\% or more, if desired, but 20\% gives a beautifully flat response curve, and is adequate. Since NFB greatly improves signal to noise ratio, the unit is remarkably quiet under maximum gain conditions.

The percentage feedback of the type of loop employed in Fig. 2 is expressed as \( \frac{R_g}{R_g+R_f} \), but in determining the value of the feedback resistor \( R_f \) it is easier to arrange the above expression as:

\[
100 - \beta = \frac{R_g}{R_f}
\]

RF can now be easily evaluated once the percentage feedback \( \beta \) has been fixed.

If desired, \( R_f \) may be split into two series resistances, one of which is variable, thus giving a manual control over the factor \( \beta \). Such an arrangement is outlined in Fig. 4.

Tone and Volume Control

With ample feedback, a tone compensatory network may not be required unless Bass Lift or Treble Lift is desired. Such a network must not be incorporated in grid or anode circuits that are within the NFB loop. The input grid circuit of the first stage or the output circuit of the second stage are good positions. If a variable tone control is used, it should occupy the latter position, otherwise any roughness of its action will be unduly amplified in the preamplifier. For the same reason the manual volume control has been placed in the second stage, although it could well replace the final output load resistor.

However, some connected apparatus may require a different value for this grid-to-earth 0.5M\ohm resistance, and it is easier to change this than to re-position the volume control.

Under strong input signal conditions the first stage will easily overload the second unless precautions are taken. In a general purpose unit of this type, it is best prevented by incorporating a volume control of the preset pattern in the input grid circuit. For any particular operation this can be set and then ignored.

Power Supplies

The anode load resistors should be decoupled as shown in Fig. 2, and a large decoupling capacitor used. If this is too small the overall response curve will be deformed and instability incurred; 8 to 16\mu F is adequate, permitting comprehensive Bass response to be handled. This decoupling electrolytic can be a 3-capacitor can type, as shown, thus economising in space. Fig. 3 depicts an inexpensive power pack for the preamplifier, and requires little comment. A 4\mu F 500V paper dielectric condenser is in series with the heater, this avoiding losses in this direction. The total mains input power is in the region of 2.8 watts. The two pole on/off switch can be associated with the volume control in the usual manner.

Since this "AC/DC" type pack is prone to the danger of crossed polarity, the author thought it expedient to incorporate a small "testoscope" as shown in Fig. 3. This will function before the preamplifier is energised by \( S_1 \) and by touching its cap indication of wrong polarity is given by its glow. The mains plug can then be reversed before switching on. A suitable "testoscope" is the \( S_1 \)-Philips now obtainable.
A useful arrangement

In its existing form, the preamplifier may be used to drive an output valve without recourse to an extra stage of voltage amplification. There is sufficient output available to fully drive an output triode of the PX4, PX25 type, thus a good quality output may be obtained without additional feedback. If 9 per cent distortion can be tolerated at an output of 4.5 watts, a 6F6GT may be used, and the surplus gain largely eliminated by means of the preset volume control. Such an adjustment will prevent overloading of the 6F6 grid circuit at maximum setting of the manual control. By this method of adjustment, practically any power valve may be driven from the unit.

In Fig. 4, S2 comprises a two-pole two-way switch which is arranged so that the output valve may be cut out of the circuit, thus enabling the preamplifier to be used as such. Feedback has been deliberately omitted from the power stage for this reason. Should it be required to construct this unit (Fig. 4) for a specific purpose, S2 may be omitted, also the preamplifier feedback loop, and a more comprehensive feedback system incorporated. Thus the need for a separate 4-volt heater winding, as demanded by the use of a power triode, is obviated, and really good quality obtained.

Layout

In Fig. 5 the component layout of the original general purpose amplifier is shown, and this requires little comment. The author would, however, stress that whilst layout is not critical, grid leads and feedback loop wiring should be as short as possible, and the metal cases of controls earthed to chassis. The chassis can, of course, be mounted in a small wooden case and an "internal" speaker installed. The chassis used was approximately 9" x 6" x 21/2" and was of aluminium.

A SMALL TRANSPORTABLE

By M. ALLENDEN

I HAVE FROM TIME TO TIME occasion to travel, and invariably on arrival at my new abode I find that I am without radio entertainment of any sort. Such isolation prompted me to construct this set, which I felt would answer my needs.

The specifications to which it is built are therefore set by its rather ubiquitous use. A battery set was decided against at the outset, on the count that, for semi-permanent use, it would be expensive; so a mains set was decided upon. AC/DC it had to be, and by using a piece of line cord that could be plugged into the set, odd voltages like 115V could be catered for by altering the cord, or having two cords — one for 220 volts and another for a lower voltage. The narrow shape was employed so that the set could be packed easily in a bag or suitcase without being awkward, whilst the size of 8" x 5" x 2" approx. ensures that it doesn’t monopolise one’s luggage.

The construction of such a receiver is obviously rather ‘bitty,’ and cabinet and set are built together, the components being bolted to the cabinet walls. By this form of construction, however, the very valuable advantage that NO METAL parts can be
touched is realised; with an AC/DC "hot-chassis" set, this advantage will be fully appreciated. The chassis holding the tuning portion can be constructed separately, and then bolted in the cabinet frame; this simplifies wiring, and to allow for alignment the chassis can be tilted. The cabinet itself has its external design based on the American type of portable, and a glance at the photographs will show the general form which the construction takes, viz, a central frame holding the chassis, rectifier, smoothing condensers, resistors and volume control. The front supports the tuning condenser and loudspeaker, whilst the back of the set holds the aerial socket and miniature Jones socket for the power. The whole cabinet is constructed from plywood of various thicknesses, and by giving the finished product several coats of brushing cellulose, a plastic-like finish can be obtained as seen in the photographs.

For maximum performance in all locations a superhet circuit is employed, and by reflexing the IF stage more can be achieved with less valves.

Circuit Details

No claims to originality for this circuit are made, the reflex idea being widely used, but by its use a large saving in components can be made. The circuit itself is a reflex superhet, the IF stage being used both as a normal IF amplifier and first AF; this saves one valve without impairing very much the performance of the IF stage.

For those not familiar with this type of circuit, a glance at the circuit diagram will

![Circuit Diagram]

**The Cover Illustration**

The Cover Illustration shows the really fine professional appearance of the finished receiver which is the subject of this article.
show that the AF is developed in the first
instance across the diode load R5, and then
filtered for the RF component via C9, R4
and C8. The resultant AF (filtered) is now
fed to the grid of V2 via the secondary of the
first IF transformer. Amplification takes
place normally in the valve, but the AF is
taken out of the screen of V2, the resistor R6
forming the load. Thus it will be seen that
the AF is fed from the AVC line, which, having no
delay, is quite satisfactory for supplying
minimum bias. Nevertheless, it was found
that a little standing bias was necessary,
therefore the inclusion of R10. The power unit
of conventional design, resistance capacity
smoothing is employed, and advantage is
taken of the S.T.C. Centercel miniature
rectifiers. The types used are the RM1's
and, as they have a maximum voltage rating
of 135 volts, two are used in series. The
valve line-up of a UCH42, EF92 and EL91
was used mainly because the author had
those types at hand; to save space and
simplify the heater arrangement a crystal
diode is utilised.

The heaters on the original model were
wired in series/parallel in order that 0.3Amp
line cord could be used, but by shutting the
UCH42 heater with a 140Ω resistor it can be
wired in series with the other two valves,
and 0.2Amp line cord used. The latter is to,
the author's mind, the better arrangement —
for in the event of a failure, only one valve
is likely to suffer. The length of line cord,
of course, depends on the ohms-per-foot of
the type used, and if the 0.3A or 0.2A system
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is likely to suffer. The length of line cord,
and then sandpaper down with fine paper (known as "wet and dry," and used with water) until you have a smooth surface. A couple more coats can now be applied, working rapidly with a soft brush. Don't go back on your first strokes, as the cellulose tends to "pull." More sandpapering when it's hard — don't rush this stage; then another couple of coats. The last coat when definitely hard (leave at least one day to ensure this) can be polished. To polish use metal polish and a soft rag, rubbing gently but with even firmness over the whole painted area, and finally polish with a clean, soft rag; the result will amaze you as, depending on the number of coats used, a beautiful plastic-like finish will result. The main frame A is enclosed last of all, when all the holes have been drilled and filled in with plastic wood. The handle is made from two pieces of perspex laminated, cemented with any of the various cements available on the market. The metal clips are made from anodised aluminium knitting needles of any of the lower gauges, which may be obtained from most stores for only a few pence.

The dial-cum-tuning drive was cut from perspex, and is fitted to the tuning condenser spindle in the same manner as the volume finger drive, except that it is anchored by a piece of plastic which has a 6-BA screw embedded in it. The shaft of the variable condenser is drilled and tapped 6-BA, so that the finger drive/dial can be held in place without exposing any metal. The piece cut out of the front panel E can now be utilised; two holes are cut out, one a piece to allow clearance for the speaker, and another to give air access to the valves (see sketch). The whole is covered with a piece of cloth and cemented behind the speaker grille.

The front and back can be fixed to the main frame by means of spring clips which press tightly down on the flanges — if spring clips such as the type for holding screwdrivers are purchased, they can be cut in half, softened at one end and drilled. The original set only needed two clips to hold the sides on very firmly.

A lot of the wiring will have to be done when the set is practically finished, such as...
the connections to the plug, aerial socket and variable condenser; these leads should, how- ever, be just long enough to allow the sides to come away a small distance from the main frame.

Alignment
This is best done with a signal generator, but it is quite easy to align on signals — the author using the latter method.

With a short out the osc. grid, and inject 465kc/s into the mixer grid, peaking up the IF transformers for max. output. Then take the short from the osc., inject via the aerial socket 1,500kc/s, setting the condenser to about one-fifth mesh, and adjust the osc. trimmer until the signal is heard — adjust the mixer trimmer for max. output. Next set the generator to about 600kc/s and set the variable condenser to about four-fifths mesh; adjust the slug on the osc. coil, at the same time rocking the tuning condenser until the signal is heard, and endeavour to get it at four-fifths mesh. Now adjust the slug of the mixer coil for max. output. Return to 1,500kc/s again, reset condenser to original position, and adjust the trimmer on the mixer section only. Return to 600kc/s and adjust mixer coil slug only for max. response. Now plug in an aerial and trim for max. sigs. at high frequency end and low frequency end.

To align without a sig. gen., don't touch the original setting of the IF cores — or if they have been tampered with, set them at where you should be. Denco (Clacton) Ltd. coils give a range of 515kc/s to 1,545kc/s, which is 580-195 metres, so that should give you plenty to go on. Having set the osc. range, adjust the mixer trimmer and the mixer slug at the high and low frequency ends of the condenser respectively, until max. response is obtained at both ends and no further adjustment is required. Now trim the IF's on a weak signal.

The dial was calibrated directly from received stations, ink marks being put at marker points, and then the points painted on afterwards — a sig. gen. is invaluable here, but the author did it by identification of stations.

Conclusion
Although most of the construction has been described in some detail, quite a few points have not been mentioned, but careful inspection of the finished product should make them clear. The set is capable of a good performance and the audio section is such that local signals can be quite deafening, and good results are forthcoming on a fairly short, throw-out aerial.

A Christmas Card with a Difference!

The most interesting "Christmas Card" which came our way this past festive season was from Hugo Gernsback, the American technical publisher.

It was in the form of a small thirty page magazine — of normal Christmas card proportions, entitled Forecast 1954. It is the latest of a long series which Mr. Gernsback has prepared, and each edition features scientific prognostications for the future. In this latest edition, Mr. Gernsback outlines the first flight to the moon in an unnamed spaceship, equipped to televise its journey back to the earth. "A and H Bombs for Defence" forms another subject for discussion — very suitable for those who enjoy letting off Christmas crackers at every opportunity during the festive season! A miniature radio receiver in the form of a pocket watch is forecast for production in 1954, and in the medico-electronic world Mr. Gernsback strongly recommends employing it in areas of good reception, but of bad interference. (The use of variable-mu EF92 valves will give better results than the stated EF91. (The use of an EF92 in the contrast control stage of the vision receiver will make the action of the contrast control less harsh. This, however, is left to the constructor's discretion.)

The sound unit, however, incorporates an efficient ear ignition interference suppressor, which cuts down the irritating noise considerably. Its function is to clip the interference peaks off the audio signal. The diagram shows the cathode of the detector diode feeding a positive signal to the cathode of the interference suppressor diode. This diode will not conduct, however, unless its anode is made positive with respect to its cathode. This is accomplished by a variable resistor in the cathode of the first audio valve. This suppressor control, R14, is adjusted so that the diode just starts to clip the maximum sound peaks. The higher ignition interference peaks will drive the diode's cathode more positive than its anode, and the diode will cease to conduct, therefore suppressing the interference peaks.
aligning the sound receiver, disconnect it from all the other units, except the power, and plug in the aerial direct. When the alignment is completed, connect all the units together, and re-align both sound and vision units. It may be found that aligning one unit may affect the other, therefore the best balance between them must be discovered. If it is found that the vision tunes well, at the expense of the sound, or vice-versa, do not overlook the dipole aerial as a possible source of the trouble. If the dipole is not cut to the correct length, it may receive the sound signal well, but not the vision; or the vision signal, but not the sound. After all, the dipole is the first tuned stage of the television receiver. 

[To be continued]

From the UNESCO publication *Television—a World Survey* we learn that TV is now operating or about to be introduced in 52 countries. In 21 of these, public broadcasters are on the air whilst another 7 are carrying out technical broadcasts of an experimental nature. In the remaining 24, either the governments or private organisations have reached the planning stage. Some rather surprising facts are brought to light in this publication. In the Soviet Union, amateur television is widespread, where enthusiasts have built not only receivers, but an entire television centre at Kharkov. In France, communal sets have been purchased by entire villages, and placed in the school house. In Thailand, TV sets are on sale before the TV transmitter has been completed! In Mexico, it is reported that colour TV has been developed by a Mexican firm and is used for medical education at the University. It is not stated whether this is a 'closed' circuit. In Brazil, plans have been made to cover the entire country with 290 stations in 186 localities. This publication is available in this country at 9/6 and contains a wealth of material ranging from the history of television in each country, organisation, technical facilities available, types of programmes and so on, to details of colour television systems available and the training of personnel for new stations.
A valve voltmeter for aerial tuning

By JOHN PICKARD

Having met trouble of this nature for years, the author devised a "Valve Voltmeter which has been used with great success in the last three NFDs. A small 1.4 volt torch cell and a 9 volt grid bias battery have powered it for fully the 24 hours of the contest (and, in fact, were on each occasion subsequently used in the shack for many weeks). It may therefore be left switched on for the entire duration of the contest.

The unit is placed as near as possible to the aerial post of the transmitter, suitable precautions being taken to prevent any leakage of RF to ground. An insulated wire wrapped for approximately 3 to 5 turns round the aerial wire, to form a capacity coupling to the grid of the indicating valve.

The batteries should be built in with the indicator, so making it completely self-contained for easy transport and erection. It will be seen that the only controls are:

1. An on/off switch which may be used to reduce drain on the batteries, although, as already stated, this is entirely unnecessary for the duration of the contest, due to the low cost of the batteries.

2. The variable resistance which is used to adjust the bias on the valve.

The valve voltmeter requires no further description, as the accompanying diagram will be easily understood. In operation it should be switched on and the cathode bias resistor adjusted so that the micro-ammeter reads approximately 50-100μA — this setting is not critical. The transmitter should then be switched on and adjusted for proper radiating conditions. With the key depressed, the insulated input wire to the valve voltmeter should be twisted round the aerial lead until the micro-ammeter reads nearly full scale deflection — say, 450μA for 500μA FSD.

The unit is now ready for use. As a test, change the frequency of the transmitter and it will be seen how quickly and easily the PA anode and aerial condensers can be adjusted for maximum deflection on the valve voltmeter. A careful check will show that the results are as good as the more usual "dip and draw" method, which will take much longer to adjust.

A further interesting check is to adjust the transmitter by the normal dip and draw method or by using an RF ammeter, and then to see how much more accurately the transmitter may be tuned by using the valve voltmeter.
OSCILLOSCOPE TRACES

By A. B.

No. 7. MODULATED CARRIERS

Two equally effective methods of checking depth of modulation from a transmitter or signal generator can be used with an oscilloscope.

The simplest way is to couple the oscilloscope to the RF tank circuit, and set the timebase to run at, say, one third of the speed of the oscilloscope to the RF tank circuit, and set the timebase to run at, say, one third of the speed of the RF "envelope" can then be observed as well as overmodulation.

To calculate the depth of modulation, the following expression is used:

\[
\text{Depth of modulation} = \frac{A - B}{A + B} \times 100\%
\]

The transmitter must, of course, be fed with constant frequency modulation in both cases.

An Efficient MODULATED OSCILLATOR

By T. W. Dresser

While many thousands of amateurs get along in a fashion without them, there is no question that a minimum of two instruments, a multi-range meter and a modulated oscillator or signal generator, are as essential to the serious enthusiast as they are to the professional. Of these, multi-range meters are comparatively easy to construct provided one has a good milli- or micro-ammeter and a handful of resistors, and many good designs have been published in the past. Signal generators are in another class, however, and while many attempts have been made to produce a reasonably priced and efficient design for amateur construction, it is doubtful if more than a very small proportion of those have even approached the standard of quality of even the cheapest commercially-made types.

The reasons for this are not hard to find. Few home-built instruments incorporate even the minimum of items necessary for stable oscillation, let alone refinements such as negative temperature co-efficient fixed condensers; and in addition the majority of them attempt to perform the entire operation, RF oscillation and modulation, with one valve, usually a 6K8 or something similar. It can be done, but it is rather singular that the manufacturers, who are as keen as any amateur to keep down the price for obvious reasons, rarely use less than two and often use three!

Alternatively, traces giving the same information can be obtained by making the connections shown in the circuit, and Figs. D, E and F illustrate this.

The trace at G shows non-linear operation, as well as overmodulation.

To calculate the depth of modulation, the following expression is used:

\[
\text{Depth of modulation} = \frac{A - B}{A + B} \times 100\%
\]

The transmitter must, of course, be fed with constant frequency modulation in both cases.

Where, then, does amateur construction fall down? Principally in frequency stability, it is to be feared. Frequency drift, and shift, is the bogey of all receiver designers, especially in communication instruments, and a great deal of trouble is taken to reduce and control it. Similarly, with good class all-wave receivers, how often do instruction books state that the receiver should be allowed to warm up for a few minutes before tuning in a station? The explanation given is that it is to allow the receiver to "settle down" but, in actual fact, it is to give the oscillator time to reach a stable operating condition. The point about all this is, how much more frequency drift must there be in a simple form of signal generator, which is switched on and used forthwith and which, in any case, has little or no compensation for drift and no means of reducing it?

The principal cause of frequency shift in any oscillator is change in supply voltages, particularly in that of the anode. The matter is more complicated where mixer valves are concerned, as in superhet's, but we are not dealing with that now. The cure for the condition is, obviously, a regulated power supply. Frequency drift is another matter altogether, and shows itself as a decrease in oscillator frequency as the temperature of the unit increases. The effect is usually greater at the higher frequencies. The cause is rather complex but much of it is due to the use of poor dielectric materials such as ebonite, bakelite and other synthetic resins, and varnished cambric in the oscillatory circuit. Drift can be considerably reduced by using porcelain or polystyrene coil formers and insulation on the tuning condenser, and a porcelain valveholder. The remaining smaller drift can then be further reduced, indeed almost cancelled out, by using negative temperature co-efficient condensers so adjusted in relation to the other circuit components that balance is secured. Positive temperature co-efficient, by the way, is defined as an increase in capacity.
with an increase in temperature, and negative temperature co-efficient as a decrease in capacity with an increase in temperature. It will readily be seen how useful condensers of the latter type can be in oscillator circuits.

The RF circuit is quite a conventional arrangement, but the modulator may call for a little explanation, perhaps. The circuit used is such that the primary of a small intervalve transformer (1:1, 2:1 or 3:1, it is immaterial) is used as a Heising modulation choke and also as a feedback winding for the audio oscillator. The tone may be changed by altering the values of the resistor R and condenser C in the grid circuit.

Except for the regulator, which is of the gaseous type, the power supply, too, is conventional. The action of the regulator is as follows: On the application of the HT, the regulator commences to conduct, and with a high load resistance (a circuit taking little current) almost the whole of the current drain goes through the regulator. With a low load resistance (a circuit taking a heavy current) the current through the regulator is decreased proportionally. The voltage at the load, therefore, remains substantially constant. This also applies to a fluctuating DC input voltage. The resistor in series with the regulator is necessary to prevent the maximum current rating of the valve from being exceeded.
The step attenuator in the output circuit will be found very useful in adjusting the input to a receiver, and as it is made up from standard resistors there should be no difficulty in assembling it. For fine control of frequency the tuning condenser is operated in assembling it. For fine control of frequency, the tuning condenser is operated. For fine control of frequency, the tuning condenser is operated.

The tuning condenser is simply a 3\(\frac{1}{4}\) by 2\(\frac{1}{2}\) piece of Bristol board or similar drawing board, held to the panel by short lengths of 1\(\frac{1}{4}\) aluminium sheet as shown in Fig. 2A. The pointer is a piece of Perspex, 3\(\frac{1}{4}\) long by 1\(\frac{1}{4}\) wide, with a line drawn down the centre length by a razor blade, and fastened the knob by two 4-BA bolts. Fig. 2 shows the above and below-chassis layouts of the finished instrument, and also the chassis dimensions. The material used in the original was 16 swg sheet aluminium, but if there is any difficulty in getting aluminium, steel chassis and cases of similar dimensions are obtainable from Denco (Clacton) Ltd. and Webb's Radio, at reasonable cost.

Regarding calibration—in the absence of a commercial signal generator with which to check it, a pretty good job can be done by beating the signal from the generator against a known broadcast signal on a receiver. No mention has been made of the output socket. This is a standard Belling-Lee coaxial type 6045, and is used with a short length of co-axial cable and a standard Belling-Lee plug type 642F. A suitable type of dummy aerial which can be used on long, medium and short waves down to ten metres without alteration is given in Fig. 3.

It is believed the cost of making up this instrument will not exceed four pounds, and may be a good deal less with judicious buying and the help of the junk box. That of the original worked out to sixty three shillings and twopence. But whatever it is, it is a small price to pay for a generator which has some claim to accuracy and stability and which will give a good deal of satisfaction in use.

<table>
<thead>
<tr>
<th>COIL DATA</th>
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<tbody>
<tr>
<td><strong>For 500pF Variable Condenser</strong></td>
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<tr>
<td>COIL 1. 600-1000 metres 580 turns 36 swg single silk and enamel wire.</td>
</tr>
<tr>
<td>COIL 2. 150-900 metres 140 turns 36 swg single silk and enamel.</td>
</tr>
<tr>
<td>COIL 3. 65-220 metres 32 turns 28 swg single silk and enamel.</td>
</tr>
<tr>
<td>COIL 4. 15-75 metres 10 turns 28 swg single silk and enamel.</td>
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</tbody>
</table>

All windings close-wound except where indicated. Three formers, 1\(\frac{1}{4}\) diameter, of Denco (Clacton) Ltd. Polystyrene are used.

**COIL DATA**

For 500pF Variable Condenser

COIL 1. (600-1000 metres) 380 turns 36 swg single silk and enamel wire.

COIL 2. (150-900 metres) 140 turns 36 swg single silk and enamel.

COIL 3. (65-220 metres) 32 turns 28 swg single silk and enamel.

COIL 4. (15-75 metres) 10 turns 28 swg single silk and enamel.

All windings close-wound except where indicated. Three formers, 1\(\frac{1}{4}\) diameter, of Denco (Clacton) Ltd. Polystyrene are used.

BBC stations are extremely accurate in frequency and can be used to cover from 1500 metres down to 20 metres, the points at which they occur being marked in on the dial. Additional signals can be obtained from continental stations and from trawler band radiophone, Rugby shipping service, etc.

**COIL DATA**

For 500pF Variable Condenser

COIL 1. (600-1000 metres) 440 turns 36 swg single silk and enamel wire.

COIL 2. (180-610 metres) 180 turns 36 swg single silk and enamel.

COIL 3. (70-210 metres) 51 turns 28 swg single silk and enamel.

COIL 4. (15-75 metres) 15 turns 28 swg single silk and enamel.

ALL COILS ARE CENTRE TAPPED.

Coils 3 and 4 are wound on one former. Formers are 2\(\frac{1}{4}\) long.

**COIL DATA**

For 350pF Variable Condenser

COIL 1. (600-2000 metres) 440 turns 36 swg single silk and enamel wire.

COIL 2. (180-610 metres) 180 turns 36 swg single silk and enamel.

COIL 3. (70-210 metres) 51 turns 28 swg single silk and enamel.

COIL 4. (15-75 metres) 15 turns 28 swg single silk and enamel.

ALL COILS ARE CENTRE TAPPED.

No other details as for 500pF coils.

Additional signals can be obtained by tuning the condenser to another frequency and can be used to cover from 1500 metres down to 20 metres, the points at which they occur being marked in on the dial. Additional signals can be obtained from continental stations and from trawler band radiophone, Rugby shipping service, etc.

**COIL DATA**

For 350pF Variable Condenser

COIL 1. (600-2000 metres) 440 turns 36 swg single silk and enamel wire.

COIL 2. (180-610 metres) 180 turns 36 swg single silk and enamel.

COIL 3. (70-210 metres) 51 turns 28 swg single silk and enamel.

COIL 4. (15-75 metres) 15 turns 28 swg single silk and enamel.

ALL COILS ARE CENTRE TAPPED.

No other details as for 500pF coils.

**Change of Address**

Osmor Radio Products Ltd., announce that their offices, stores and despatch departments have been moved to larger premises at 418 Brighton Road, S. Croydon, Surrey (on the main Croydon-Purley Road). Telephone numbers are still CROYdon 5148/9.

Their Bridge View Works, in Borough Hill, have been moved to larger premises in future be addressed to Brighton Road. Telephone numbers are still CROYdon 5148/9.
The following features of these transformers are particularly worthy of merit:—

The recording level meter, of course, should not be mounted until wiring has otherwise been completed, in order to

The holes shown dotted on side A are located by holding the chassis up to the deck, after the latter has been drilled, and then temporarily locking the two in position by means of the input and output sockets whilst the hole positions are marked on the chassis by means of a scriber, or similar sharp pointed instrument. Alternatively — and this will ensure a better register—the holes may be drilled whilst the deck and chassis are locked together, the deck acting as a jig.

After the edges of the holes have been cleaned up, assembly may be commenced, starting with those components which are attached to the deck—in other words, the controls. The recording level meter, of course, should not be mounted until wiring has otherwise been completed, in order to

We have received from the G.P.O. the following announcement relating to the testing of applicants for Amateur Transmitting Licences in Morse Code operating.

"As from the lst January, 1954, prospective Amateur Licence holders will no longer be given their Morse test at any Head Post Office. The tests will be conducted on request at:—

(b) Post Office Coast Stations, i.e. Burnham, Cullercoats, Humber, Land's End, Niton, North Foreland, Oban, Port Patrick, Seaforth, Stonehaven and Wick.

In order to meet the need of applicants who cannot conveniently reach the above places, tests will also be held, provided there are sufficient candidates, twice a year (January and September) at the following Head Post Offices:—Birmingham, Cambridge, Derby, Leeds and Manchester.

Constructors of portable equipment, miniature and radio control receivers, etc., will be interested in a new range of small transformers in encapsulated block form available from John Bell and Croydon, 117 High Street, OXFORD.

The following features of these transformers are particularly worthy of merit:—

Fixing screws are moulded into the block and are an integral part of the unit. Rigid terminal pins are supplied in place of loose lead-out wires. Chassis mounting is simplified and when impregnated they are proof against damp and suitable for tropical conditions. Full details can be had upon application.

Mullard Ltd., announce two new valves which have been specially designed for use in domestic radio and television receivers at frequencies up to 220 Mc/s. These valves will enable sets to be designed for reception of transmissions in the V.H.F. broadcast band (Band 2) and the "competitive TV" band (Band 3).

The new valves are a double triode, type PCC84, and a triode pentode, type PCF80, both on a normal base. The PCC84 is designed for use as a "cascade" low noise R.F. amplifier, and the PCF80 is intended for use as a frequency changer following an R.F. stage employing the PCC84. Both valves have 0.3A heaters and are suitable for use in AC/DC sets where the heaters are connected in series. They operate effectively on an HT voltage as low as 180V.

The Radio Amateur Emergency Network (R.A.E.N.) recently organised by the RSGB, received good publicity in the national press and radio.

Progress is proceeding well, some 28 local organisers having been appointed to date. It is open to any radio amateur whether he be a member of the RSGB or not, and enrolment forms can be obtained from the Organising Secretary, R.A.E.N. c/o RSGB, New Ruskin House, Little Russell Street, LONDON, W.C.1.
The Amateur Spirit is quite an old-timer in radio writing, and experimental work on model control and readers both for his activity on the air under his call-sign G2UK, as well as for his contributions to radio journalism. He will find expression in a new form, and not of the Council, his experience and enthusiasm for me now to announce that he was elected widening of its scope. In other words, it is a war interest in amateur radio is falling back on the specialisation. It was holding its own despite the inflated post-war figures in the amateur movement, natural and unlikable the pretended bonhomie of a few type have aggravated the situation by their condescending treatment of even the more "superior" group have been allowed to feel neglected. While it is true that such important people were behind it, but to our great relief one or two of them wondered what they thought when they saw a couple of schoolboys in knickerbockers take their seats. Luckily nobody said "Who let the dog in?" — and a reassurance to those whose names were familiar as contributors on amateur affairs, in pre-War days, together with a school-chum, writing off to the Ascot Meeting! Alas, a few of the "superior" type have given up for the Ascot Meeting, and we felt awfully proud, especially when they "suggested" that we should have curled up with shame. Instead we sat there marvelling and scarcely daring to breathe. Naturally we had not realised that our great relief one or two of them even spoke to us and gave us a few words of encouragement after the Meeting finished. We felt awfully proud, especially when they let us sign some sort of petition they were presenting to the PMG or some other bigwig. I've often wondered what the PMG, or whoever it was, would have thought if we had put "aged 13" after our signatures. I recall we left the Meeting feeling like a couple of millionaires. Naturally we'd have loved him able to cock a snoot at the Commissioner, but of course our newly-acquired sense of dignity ruled that out. I am sure that if we had had the money we would have left by taxi. As it was, we walked part of the way home to save the fare. With the money saved we stopped at a coffee-stall for a cup of tea, which we furtively drank hoping that nobody from the Meeting would see us.

As I say, you can't start too young — but there was no organisation for us to get into in those days, let alone provision for junior members. As a result, my schoolboy companionship is now a high-ranking Naval Technical Officer, although I haven't seen him for years. Inwardly I have always blamed him for leading me into that affair, but I guess his sense of Naval discipline still relaxes when some young cadet's zeal gets the better of his discretion.

TV And All That

In recent weeks I have been greatly surprised to find there still are people who hold back from buying a TV receiver, for fear the market will be suddenly flooded with sets costing between £25 and £50. It is hard to discover quite why they should be suspicious about the modern set, as invariably they are extremely vague about what is it they expect to happen. They seem to have a curious idea that mass production will bring prices down with a rush. Such a notion is absurd. When you discount Purchase Tax, current prices are amazingly low. With the present system, a receiver is only £25. This is not because it is an expensive CRT and several well-designed circuits which must have a high order of stability. Further price reductions could only be made at the expense of quality, and the use of cheap components might easily put the purchaser to greater expense in servicing costs than the cost of the receiver, within the first twelve months.

Others seem to nurture a fear that some cunning "Cartel" is holding back for an opportune moment to bring out a cheap set of revolutionary design. That, again, is simply nonsense. True, there may be a revolutionary design. I should be the last to suggest that a monster-sized CRT for direct-viewing is the final word in design. But if anything really new comes along, it will take years in the developing.

The only other alternative is projection TV, and that will certainly be no cheaper than direct viewing. True, it does save on the large-size CRT, but you still want a super-brilliant one. The need for an EHT supply of up to 20,000 volts and a separate screen.

As we decided in this column long since, TV inevitably involves a heavy outlay, and the hire companies who charge a weekly FEBRUARY 1954

Centre Tap talks about The Radio Amateur - The Amateur Spirit - Commercial TV

We were simply overwhelmed when we discovered that several very well-known scientific figures were present — in fact everybody there looked, to us, like Important Scientists, or, at the least, University Professors. I have often wondered whether they thought when they saw a couple of schoolboys in knickerbockers take their seats. Luckily nobody said "Who let the dog in?" — and a reassurance to those whose names were familiar as contributors on amateur affairs, in pre-War days, together with a school-chum, writing off to the Ascot Meeting! Alas, a few of the "superior" type have given up for the Ascot Meeting, and we felt awfully proud, especially when they let us sign some sort of petition they were presenting to the PMG or some other bigwig. I've often wondered what the PMG, or whoever it was, would have thought if we had put "aged 13" after our signatures. I recall we left the Meeting feeling like a couple of millionaires. Naturally we'd have loved him able to cock a snoot at the Commissioner, but of course our newly-acquired sense of dignity ruled that out. I am sure that if we had had the money we would have left by taxi. As it was, we walked part of the way home to save the fare. With the money saved we stopped at a coffee-stall for a cup of tea, which we furtively drank hoping that nobody from the Meeting would see us.

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rental of £5 upwards are not making their fortunes out of it. Now that knock-out price components and valves are disappearing from the market, the home constructor does not show any very great saving unless he's clever at improvisation. In fact, it is actually cheaper to build a set from specified parts. Even so, the home constructor gets lots of extra fun out of it and he wins hands down on the score of running costs. His really big advantage comes when he decides on something bigger, or of later design (such as when we want tuneable sets for a second programme) when most of his components, etc., can be carried over into the revised edition. The ordinary viewer will, of course, be able to get a converter, but that means extra bits and pieces and another power supply.

Confession

Talking of alternative programmes reminds me that a certain MP, who seems to spend all his time on this side of the waterways, has discovered that it is going to be an Awful thing for the children. Fancy letting the poor little blighters have the choice of programmes when there is such a dreadful risk they might not choose the BBC.

I have yet to see anyone give a satisfactory answer to the points we have raised in this column.

RUFUS—THE RADIO CONSTRUCTOR

ONE Is it good to have only one employer of broadcast talent?

TWO It puts too much power in the hands of too few people.

THREE Any monopoly grows big and clumsy and, when Government controlled, gets stiff with bureaucracy.

FOUR New technical developments are dominated by the old.

FIVE Bureaucrats prefer to do nothing rather than risk doing anything which either does not suit their organisation, or might not please the people that matter.

SIX Who can doubt that BBC programmes will improve when they have got to fight to retain their audiences?

SEVEN If advertising is so degrading, should the BBC be allowed to collect millions selling space in their publications?

EIGHT Would anyone seriously propose we should have our theatres controlled by one body, only one film company, or a single newspaper?

Now for a fearful admission. I don't want more TV, or even colour! From an amateur transmitting point of view I think the short-wave and VHF spectrums are already far too crowded, and that we are in grave danger of becoming a nation of watchers rather than a nation of do-ers.

FEBRUARY 1954

Query Corner

A Radio Constructor Service for Readers

Receiver Whistles

I am finding that reception on the medium wave band is becoming increasingly marred by whistles, the effect being much more apparent during the early hours of darkness. The set is a standard five valve superhet and, thinking that the interference was caused by maladjustment of the tuned circuit, I have had the alignment checked without any appreciable improvement. Is it possible to modify the receiver to effect some improvement?

D. Barnes, Brighton

Whistles may be regarded as the audible counterpart of the patterns which sometimes mar television reception. They can unfortunately be due to a variety of causes, and it is perhaps useful to consider these in turn. They may be divided as follows:

1. Constant whistle which does not vary as the tuning is adjusted.
2. Whistles which vary only in intensity as the tuning is varied.
3. Whistles which vary in both intensity and pitch with the tuning.

Category 1

A whistle which is independent of the tuning control is almost certainly due to instability in the audio side of the receiver. It will occur even when the aerial terminal is shorted to earth. The remedy lies in checking all anode and screen grid decoupling components and adding further decoupling if necessary. If the receiver is battery powered and the HT battery partially run down, the inclusion of a 2µF capacitor across the HT may effect a cure.

Microphony also falls within this heading, and may be due to a faulty valve or vibrating tuning condenser vanes. The source may be easily located by gently tapping suspected components. Anti-microphony valveholders and a resilient mounting for the tuning condenser are possible remedies for this problem. If a resilient type of valveholder is used, the leads to the connecting tags must be reasonably flexible to prevent vibration being conveyed to the valve via the leads.

Category 2

Whistles which only vary in intensity with the tuning are not normally due to the receiver, but are the beats formed between the carriers of adjacent signals. Broadcast stations are usually spaced 9 kc/s apart on the medium wave band, and stations on adjacent channels are normally located some considerable distance apart. However, particularly after dark when conditions for long
distance reception are most favourable, this form of whistle may occur. Congestion on the medium wave band has been getting progressively worse since the war; there are, for example, many districts in which reception of the London Home Service is marred after

However, there are two simple methods of bringing about some improvement on standard receivers. The first is to provide a tuned filter to remove the whistle from the audio side of the set. The second solution lies in rejecting the unwanted signal which is causing the beat note. The circuit diagram in Fig. 1 indicates a typical diode detector circuit to which a whistle rejector has been added. The extra components are L and C, and these are sharply tuned to the unwanted frequency. To reject a 9 kc/s note, L should have a value of 0.8H and C a value of 500 pF. The coil must be well screened to prevent the pick up of hum from stray fields within the receiver.

The unwanted signal rejector or wave trap is shown in Fig. 2. This rejector is sharply tuned and located as close as possible to the aerial terminal of the receiver. It is tuned to the signal which is causing the beat note on the wanted carrier and, as already explained, it will be resonant some 9 kc/s away from the required signal. If there are two stations which are masked by whistles it is possible to employ two such rejectors in the aerial circuit. Rejectors of this type are made by the Osmor Company, and when ordering it is necessary to state the frequency to which they are to be tuned.

If the whistle appears on all stations regardless of the position on the dial, the trouble may be due to interference from a signal which is adjacent to the intermediate frequency of the receiver. In this case the solution lies in the use of an aerial circuit rejector as shown in Fig. 2, but the trap must be tuned to the intermediate frequency.

A whistle having a rough note and occurring only at the high frequency end of the tuning range indicates that the local oscillator in a superhet receiver is squeeging. To prevent this, a 47 ohm carbon resistor should be connected directly in the lead to the grid of the oscillator section of the frequency changer.

Category 3 Whistles which vary in both pitch and intensity may be due to instability in the RF stages of the receiver. The causes of this trouble have been discussed on many occasions, and lies in checking the decoupling components and the earthing of metal screens. In superhet receivers the trouble may be rather more difficult to cure, because there are many combinations of signal, oscillator and IF harmonics which can cause whistles. With the exception of IF harmonic feedback, the possibility of this trouble is reduced as the preselection, or RF sensitivity and gain is increased. The first step, therefore, is to ensure that the RF stages are accurately aligned and that the RF valve is operating correctly. Most forms of interference of this type are also less likely to occur as the intermediate frequency is increased, and for this reason an IF of around 465 kc/s is superior to one of 110 kc/s. Harmonics of the IF can be recognised because they are usually tuned in as whistles on frequencies of two or three times that of the intermediate frequency. These harmonics are usually generated at the detector stage or in the last IF amplifier, particularly if the latter has a tendency to overload on strong signals. The remedy lies in reducing the unwanted coupling between RF and IF stages. Such coupling may be via HT or A.V.C lines or simply by stray capacitance. Very careful screening of the leads and components associated with the detector stage is most important. If the trouble still persists, however, an IF harmonic rejector circuit may be added in the output lead from the detector. The circuit is as shown in Fig. 1, but in this case the L-C combination is tuned to the IF harmonic which is causing the whistle. Once again the components in the rejector circuit must be carefully screened, but this time the screening is necessary to prevent radiation of the unwanted harmonic.

It is hoped that these notes will assist readers in tracking down and eliminating at least most of those annoying whistles which beset some medium wave listeners.

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**CLUB NEWS**

**An Amateur Tape Recording Society has been formed by Mr. F. H. Hollis, 143 Lymington Avenue, Leigh-on-Sea, Essex.**

The idea is to encourage the use of tape recording as a medium of correspondence. Each member contributes on to tape and the tape is then sent to the next member. The tape is then added. The extra components are L and C, and these are sharply tuned to the unwanted frequency. These harmonics are likely to occur as the intermediate frequency is tuned in as whistles on frequencies of two or three times that of the intermediate frequency. Such coupling may be via HT or A.V.C lines or simply by stray capacitance. Very careful screening of the leads and components associated with the detector stage is most important. If the trouble still persists, however, an IF harmonic rejector circuit may be added in the output lead from the detector. The circuit is as shown in Fig. 1, but in this case the L-C combination is tuned to the IF harmonic which is causing the whistle. Once again the components in the rejector circuit must be carefully screened, but this time the screening is necessary to prevent radiation of the unwanted harmonic.

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**CHESTER AND DISTRICT AMATEUR RADIO SOCIETY**

**CLUB REPORT FOR FEBRUARY 1954**

The Chester and District Amateur Radio Society held its annual general meeting at the quarter of the year on the 5th January, 1954, when a Auction Sale was held, with G2YS calling the QDs.

On the 12th January, a very interesting lecture was given on an All Band TX, portable, by B. O'Brien, (G2AMV) Regional Representative. The talk was illustrated with excerpts from both LP and standard 78 r.p.m. recordings. January 1st again attracted a large gathering for the Reel Exchange, and is proving an attraction to licenced members.

The monthly News Letter is available to all interested on application.

The List of the Club Station on the "AIR" of a medium of correspondence.

A Top Band QRP Net has recently commenced, and is proving an attraction to licensed members. All stations with the common interest of QRP are welcomed on the Net, which is held on the frequency of 1,900 kc/s, at 1430 GMT., every Sunday, SWL reports would be very acceptable.

All those interested in the low power aspect of wireless communication, be it receiving, transmitting, or even radio control of models, are invited to join the QRP Society. Everyone is welcome at the meetings, and any interested are invited to give us a call.

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**ORP RESEARCH SOCIETY**

One of the latest Society Services—"The Student Assistance Scheme"—shows great promise. This scheme caters for the novice to the hobby of amateur radio, and arranges for him or her to be instructed in radio theory, and to be given that "helping hand" over the pitfalls that can discourage so many an enthusiastic beginner. This Service is entirely free of charge, each novice being personally supervised by an experienced member of the Society through the medium of correspondence.

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Let's Get Started

9: A SENSE OF VALUES

By A. BLACKBURN

The Easy Way to the Right Component

Last month we looked into some of the factors involved in the design of an audio amplifier. The specific details, however, were ignored—for example, all the grid bias voltages were derived from some mysterious source marked 'G.B.' In practice, of course, particularly in mains driven equipment, the required bias is derived from a resistor in the cathode circuit of the valve. You are also frequently faced with the problem of estimating the correct wattage rating for resistors.

Fortunately, it is not a difficult matter to avoid those dense clouds of smoke resulting from an overloaded resistor, burning happily away somewhere in the heart of a newly constructed instrument.

It is hoped that this article may help to avoid some of the minor disappointments and difficulties which face everyone when the published design is cast aside, and an experimental design of one's own attempted.

Series and Parallel

We will start at the beginning and talk about resistors, capacitors and inductors in series and parallel, in that order.

Figure la shows two resistors in series, the total resistance being \( R_1 + R_2 \). The voltage developed across them can be calculated in two ways. If the current \( I \) flowing through them is measured, the voltage across \( R_1 \) is, from ohm's law, \( IR_1 \), and across \( R_2 \) is \( IR_2 \).

If, however, the voltage \( V_1 \) is known, but the current is not, \( V_2 \) can be calculated from the expression:

\[
V_2 = \frac{R_2}{R_1 + R_2} \times V_1
\]

This is only true when no load is placed across \( R_2 \). The voltage across \( R_1 \) is, therefore,

\[
V_1 = V_2.
\]

All you have to do is to find the total resistance of a number of resistors in series is merely to add the values together.

Figure lb shows two resistors in parallel. In this case, I'm afraid, finding the total resistance \( R_T \) is a little more complicated. It is evaluated by using the expression:

\[
R_T = \frac{R_1 \times R_2}{R_1 + R_2}
\]

The original value of 200 Ohm must have 1800 Ohm wired in parallel with it to produce the required 180 Ohm. In practice, 2000 Ohm would be chosen as this is a readily obtainable value, the error in the final result being very small.

Capacity and Inductance

Suppose we now substitute two capacitors, \( C_1 \) and \( C_2 \), for the resistors \( R_1 \) and \( R_2 \) in Fig. 1a. We can calculate the resultant capacity \( C_T \) from the expression:

\[
C_T = \frac{C_1 \times C_2}{C_1 + C_2}
\]

The similarity between this expression and the one for resistors in parallel is readily apparent. Substituting \( C_1 \) and \( C_2 \) for the resistors \( R_1 \) and \( R_2 \) in Fig. 1b gives us the total capacity \( C_T \):

\[
C_T = \frac{C_1 \times C_2}{C_1 + C_2}
\]
The Bias Resistor

Fig. 2 shows a self-biased audio stage. It is often necessary, when designing an amplifier, to calculate the value of the bias resistor $R_b$. This is to ensure the correct bias voltage. As a rule, manufacturers state the bias voltage and the relevant current through the valve for this bias. Sometimes they also give the value of $R_b$, but if this is not included then only a simple equation to assess its value is required.

A valve with a cathode current of 40 mA and a required bias of 8 volts gives a bias resistor value of $R_b = V_b = 8 \times 1000 = 2000 \Omega$.

(Please note that there is a error in the original text as the correct calculation should be $R_b = V_b / I_c = 8 / 0.04 = 200 \Omega$.)

The wattage is $P = I^2 R = 0.04^2 \times 200 = 0.32$ watts.

A half watt resistor is called for here.

In most cases the resistor is bypassed in order to prevent loss of gain. The value of this capacitor, although not critical, varies with the bias resistor. For correct functioning it should remain charged throughout the period of one cycle of the lowest frequency to be amplified. For instance, the period of one cycle of a 100 c/s signal is obviously 1/100 second, and the condenser must remain charged throughout this period.

A resistor and capacitor connected as shown in Fig. 2 have a property known as the ‘time constant.’ This means that a capacitor takes a definite time to charge and discharge through a resistor. The time constant ($T$) is given by the expression:

$$T = R C$$

Where $R$ is in ohms and $C$ is in farads.

Assuming as before that $R_b$ has a value of 200 $\Omega$ and the lowest frequency is 100 c/s, the capacity becomes:

$$C = 0.01 \text{ (sec) \times 0.00005 \text{ F}} = 50 \mu F.$$
The value of the resistor is fixed by the manufacturer's recommended voltage and current.

If we have a current of 1 mA, a voltage of 200 volts, and an HT voltage of 250 volts, it follows that the voltage to be dropped is 50. To find the value of resistor we want, we use:

\[ R = \frac{E}{I} = \frac{50 \text{ volts}}{1 \text{ mA}} = 50 \text{ k}\Omega. \]

The decoupling capacitor can now be calculated, in the same way as in the case of the cathode, by using the expression:

\[ T = CR \]

Assuming 100 c/s is the lowest audio frequency, the decoupling capacitor is evaluated by

\[ T = \frac{1 \text{ sec}}{100} = 0.01 \text{ secs.} \]

\[ = \frac{0.01 \text{ secs.}}{50 \text{ k}\Omega} = 0.2 \mu\text{F}. \]

RF Stages

The principles for decoupling anodes, screens and cathodes of RF valves are the same as for the audio frequencies we have already explained. However, there is little point in calculating the values of decoupling capacitors because the lowest frequency to be amplified is normally higher than 100 kc/s. It is good practice to calculate the values for a stage dealing with a frequency of this order. You will find that the capacitor values are very small, usually below 0.1\mu F, and so, in practice, a capacitor of 0.1\mu F is used. It is a good idea to place a 500 pF capacitor in parallel with the 0.1\mu F. The reason for this is that capacitors of relatively high values, say above 0.01\mu F, are very often inductive, by virtue of their construction. Sometimes they are 'lossy', and their effectiveness is reduced at high frequencies. The addition of a high quality capacitor of small value helps to overcome this effect.

Gain

There are often times when it is very useful to be able to get an approximate idea of the gain of a stage without having to trouble about drawing the load line. All you need to know is the \( \mu \), \( gm \) and \( Ra \) of the valve concerned. As you are nearly always given two of these three quantities, in the manufacturer's data, the third may easily be worked out, if required, by

\[ \mu = \frac{gm \times Ra}{Rl}. \]

Supposing \( gm \) and \( Ra \) are 5.5 mA/volt and 10k\Omega respectively, then

\[ \mu = \frac{5.5 \times 10}{50} = 55 \]

working, of course, in mA and k\Omega.

With triode stages, unfortunately, the anode load must also be known before we can calculate its gain. The gain is then given as

\[ \text{Gain} = \frac{\mu \times Rl}{Ra + Rl}. \]

At this point I must emphasise that the gain of a triode can never exceed \( \mu \). Now if the required gain is known and we want to find out the value of the load resistor \( Rl \), we use

\[ Rl = \frac{A \times Ra}{\mu - A}. \]

If \( A \) were to be equal in value to \( \mu \), the denominator of this equation i.e. \( \mu - A \), would become zero and \( Rl \) would therefore become infinite, which as you know is impossible. Always make sure that you do not try to calculate \( Rl \) for a gain of 100 if \( \mu \) is only 50. It just can't be done!

Let's see what result we get when we give values to \( gm \), \( Ra \) and \( \mu \), and use this expression to find \( Rl \). With a gain of 30, a \( \mu \) of 50 and an \( Ra \) of 10k\Omega,

\[ Rl = \frac{30 \times 10,000}{50 - 30} = 15k\Omega. \]

For a gain of 45 with the same valve, \( Rl \) would be

\[ Rl = \frac{45 \times 10,000}{50 - 45} = 90k\Omega. \]

Despite the more complicated appearance of the pentode, the expression for the gain of a pentode stage is simpler than for a triode. It is

\[ A = gm \times Rl. \]

Since the \( \mu \) of the pentode is very high, we need not worry about limiting our gain as before. So for \( Rl \) we get

\[ Rl = \frac{A}{gm}. \]

For a gain of 100 and a \( gm \) of 5 mA/volt

\[ Rl = \frac{100}{5} = 20k\Omega. \]

The load line method is a more complete guide to the capabilities of a stage than the systems outlined above, which are not intended to give any more than a good estimate of what to expect.

DESIGNING A MULTIRANGE METER

By R. K. VINYCOMBE

B.Sc.

MOST MULTI-RANGE METERS consist of a basic current-measuring movement with circuits which enable it to read on a variety of different ranges. Some of the more expensive commercial instruments incorporate elaborate switching arrangements, overload protection and so on, which make them easy and quick to use. Many of us, however, cannot afford such luxury and this article describes how a meter covering nearly all the usual requirements can be constructed without any complicated wiring or switching.

Principles

The basic movement should be a moving-coil meter having as small a current range as possible. 1mA is adequate but 500\mu A is better. The higher the sensitivity of the meter—that is, the smaller its full-scale deflection—the less interference it is likely to cause in the circuits where it will be used. To enable this meter to read higher currents, it is necessary to by-pass some of the current through a shunt. The most convenient form of shunt consists of a tapped resistor \( Rl \) connected in parallel with the meter as shown in Fig. 1. One end of the shunt is the common negative terminal while the tappings form the connections for the various current ranges. Provided that the internal resistance and the full-scale deflection of the meter are known, it is possible to calculate the value of the shunt and the position of the tappings. It is best to make the full-scale deflection on each range a convenient multiple (say 10) of the next lowest range. With a 500\mu A meter, therefore, the shunted ranges will read 5mA, 50mA and 0.5A; whereas with a 1mA meter the higher ranges may be 10mA, 100mA and 1A.

\[ R = \frac{E}{I} = \frac{50 \text{ volts}}{1 \text{ mA}} = 50 \text{ k}\Omega. \]

If the full-scale readings for each range are \( I_1 \), \( I_2 \) and \( I_3 \), the full-scale reading of the
Fig. 2. A common negative terminal can range and each resistor can be connected. A separate resistor is provided for each of Ohm's law, the meter is made to measure in series with the meter, as is shown in the current, through a known resistance.

Fig. 2. The milliammeter and multipliers may be made by taking:

For the milliammeter and multipliers arranged to give a number of voltage ranges

Some resistors for the AC voltage range as are provided for each voltage range, designated $V_1$, $V_2$, $V_3$ and $V_4$ in the figure. For a 500mA meter, suitable voltage ranges are 0.5V, 5V, 50V and 500V. With a 1mA meter, ranges of twice these values make dial readings convenient. The "multiplying" resistors, $R_4$, $R_5$, $R_6$, $R_7$ are all calculated in the following manner: where $V$ is the full-scale voltage range required and $R$ is the appropriate value of multiplying resistor for that range:

$$R = \frac{V}{(I_m - Im)}$$

where $I_m$ and $R_m$ are the full-scale current and internal resistance respectively of the basic meter. The "ohms-per-volt" of a voltmeter is an indication of its quality. A high value means that the meter causes less disturbance in the circuit to which it is connected. However, since Ohm's Law states that current is equal to "volts-per-ohm", the "ohms-per-volt" of our instrument is simply the inverse of the full-scale current of the meter, A 500mA meter gives 2,000 ohms-per-volt and a 1mA meter gives 1,000 ohms-per-volt.

For many applications in radio, it is very useful if a measurement can be made of AC voltage, and this facility can readily be added. Alternating current measurement, however, are more difficult and are not provided for in the instrument being described. Fortunately, AC voltage checks are all that are normally required in the average radio constructors work. To enable the meter to make these measurements, a rectifier is necessary to ensure that only direct current flows through the meter itself. Suitable rectifiers are usually made in stacks of four units and are connected to form a "bridge" as shown in Fig. 3. Alternating current applied through one pair of opposite corners of the bridge causes a direct current to flow through the other corners via the meter. Rectifiers connected in this manner result in a current flowing through the meter which is equal to the average value of the AC applied to the rectifier. We usually require to know the root-mean-square (RMS) voltage which differs from the average value in most cases. Providing we know the waveform of the alternating current, it is possible to convert from average to RMS values by multiplying the former by a constant known as the "form factor". For instance, the form factor for a sine wave (such as the normal 50 c/s mains supply) is 1.11. A reading of 207 volts average would therefore indicate an RMS value of 230 volts.

There are two ways out of this difficulty. The simplest is to use the same multiplying resistors for the AC voltage range as are used on the DC range and to remember that it will always be the average value of AC which is read on the meter. To obtain RMS values, the readings will have to be multiplied by the form factor—in most practical cases, by 1.11. This is the scheme adopted in the meter described.

A more elaborate solution, which some constructors might like to incorporate, is to adjust the sensitivity of the basic meter to compensate for the factor of 1.11 which is introduced when reading RMS AC volts. Such compensation will only bring the scale readings correct when the applied voltage has sine waveform. It is achieved by shunting the basic meter with two different resistors. When used for the measurement of DC volts, it has a full-scale deflection current of 1.11 times the current required when connected to the rectifier. A circuit for achieving this is shown in Fig. 4. It will be seen that a 3-pole switch is required, although this may be part of a selector switch already incorporated in the instrument. When switched to DC the shunt resistor $Rs$ is connected across the meter. It is usually convenient to make this resistor equal in value to the internal resistance of the meter, $R_m$, in which case the full-scale current for the meter will be doubled, i.e. a basic 500mA meter will take 1mA to give full-scale deflection. It is important to remember that the modified full-scale current must be used in the calculations to obtain the values of the multiplying resistors $R_4$ to $R_7$ as described above. Also, the value of internal resistance, $R_m$, in which case the full-scale current used in these calculations, is the resultant of the meter resistance, $R_m$, and the shunt resistor, $Rs$, in parallel. If these resistors are made equal, then the effective internal resistance is $\frac{R_m}{2}$. Now when switched to AC, the meter must read 1.11 times higher. This results in AC volts being indicated accurately when applied to the

Fig. 4. The use of compensating shunts $Rs$ and $R_9$ on the AC and DC voltage ranges

Fig. 5. The meter used as a continuity tester. "S" is a dry cell

In practice this ratio may be found by experiment. Another feature which can be readily added to this kind of meter is a continuity tester. It consists of a single dry cell and a variable resistor connected to the positive terminal of the meter, as shown in Fig. 5. Two leads and test prods enable wiring to be traced readily. The prods are first held together and the variable resistor $R_9$ adjusted so that the meter reads full-scale.
The two tapping points R2 and R3 may, in practice, be determined by experiment as described later, but for those who wish to provide an adequate approximation for each voltage range, designated V1, V2, V3 and V4 in the figure. For a 500uA meter, suitable voltage ranges are 0.5V, 5V, 50V and 500V. With a 1mA meter, ranges of twice these values make dial readings convenient. The "multiplying" resistors, R4, R5, R6, R7 are all calculated in the following manner: where V is the full-scale voltage range required and R is the appropriate value of multiplying resistor for that range:

\[ R = \frac{V}{I_m} \]

where I_m and R_m are the full-scale current and internal resistance respectively of the basic meter.

The "ohms-per-volt" of a voltmeter is an indication of its quality. A high value means that the meter causes less disturbance in the circuit to which it is connected. However, since Ohm's Law states that current is equal to "volts-per-ohm", the "ohms-per-volt" of our instrument is simply the inverse of the full-scale current of the meter. A 500uA meter gives 2,000 ohms-per-volt and a 1mA meter gives 1,000 ohms-per-volt.

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There are two ways out of this difficulty. The simplest is to use the same multiplying resistors for the AC voltage range as are used on the DC range and to remember that it will always be the average value of AC which is read on the meter. To obtain RMS values, the readings will have to be multiplied by the form factor—in most practical cases, by 1.11. This is the scheme adopted in the meter described.

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\[ R_s = \frac{0.89}{1.25} \approx 0.71 \]

In practice this ratio may be found by experiment.

Another feature which can be readily added to this kind of meter is a continuity tester. It consists of a single dry cell and a variable resistor connected to the positive terminal of the meter, as shown in Fig. 5. Two leads and test prods enable wiring to be traced readily. The prods are first held together and the variable resistor R9 adjusted so that the meter reads full scale.
A Simple Practical Instrument

A circuit diagram of an instrument designed on the lines described above is shown in Fig. 6, and the appearance of the completed unit can be seen from the accompanying photographs. A 2-inch dial ex-government 500\(\mu\)A meter was used as the basic movement and this is mounted in the centre of a paxolin panel. The multiplying resistors, shunt and rectifier are wired into the circuit at the back of the panel. One “common” terminal is provided and there is a separate terminal for each of the current and voltage ranges. For those who prefer to use the same pair of input terminals for all ranges, a multi-way switch could obviously be arranged to connect the input terminals to the appropriate part of the circuit. A word of warning is necessary here, however, since the contacts of this switch must be capable of carrying up to 0.5A (on the highest current range) and withstanding potentials in excess of 700 volts peak (on the highest AC voltage range). The ordinary wave-change type of wafer switch is not usually satisfactory in these respects. A terminal is also provided for continuity testing, making a total of 13 ranges. One of the knobs on the front panel is for the selection of “AC volts,” “DC volts” and “milliamps,” while the other is the zero adjustment for continuity testing. A terminal is also provided for earthing the metal box which contains the instrument. A clip, made from a small piece of sheet brass, is bolted to the front panel and holds a pen-torch cell in position. The body of the cell connects with the clip while another brass contact strip bears against the central positive pole of the cell.

It will be seen from the circuit that, in the interest of simplicity, no compensating shunts are used on the voltage ranges. Since the same terminals are used for both “AC volts” and “DC volts,” the meter reads average voltage on the AC ranges, and this must be remembered when making measurements, as explained earlier. Also, in order to make use of the maximum current sensitivity of the meter, the lowest current range (500\(\mu\)A) is operative when the instrument is switched to “DC volts.” The remaining current ranges, however, depend upon the universal shunt (R1, R2 and R3) and this is brought into circuit in the “milliamps” position of the selector switch. The continuity-testing circuit is available when the selector is set to “DC volts.”

Construction

When a suitable meter has been obtained, it is first necessary to determine the value of the internal resistance. This may be marked on the meter dial, but, if not, the following method of determination gives a result of sufficient accuracy.

Set up the meter in series with a dry battery and fixed resistor so that a deflection near full-scale is obtained. A 9-volt battery and an adjustable resistor so that a steady current passes. The battery should be of at least 9 or 10 volts. The meter is operated on its lowest current range, where the shunt is not in circuit. The resistor is then adjusted so as to obtain nearly full-scale deflection. The meter is then connected to the next highest range and the shunt adjusted until the meter reads one-tenth of its previous value. The adjustable resistor is next altered so as to increase the current until full-scale deflection is again reached. The meter is then changed to the next highest range and the procedure repeated until a reading of one-tenth the previous indication is obtained. This procedure is repeated until all the sections of the shunt have been checked. When this is done, the factor of 10 between each current range can be readily achieved.

The values of the resistors for the four voltage ranges are given in the list of components. These resistors should preferably be of the type with a guaranteed accuracy of 1/\(\%\), although 5\% may be good enough for many purposes. The multiplier for the 0.5 volts range may have to be made up from two or more resistors in series or in parallel, if the exact value is not readily available. The zero-adjusting resistor, R10, is split in two parts. The fixed portion, R10A, ensures that a current sufficient to...
damage the meter cannot pass if the variable resistor R10a is inadvertently turned "all out" when the test prods are shorted. Sufficient adjustment is still available on the 5-volt AC range. For the same reason, the 0.5V AC range can be little more than a voltage detector. AC voltages indicated on this range will always be much higher than the readings shown on the meter. This range can, however, be used for the detection of small AC voltages where their actual values need not be known. These limitations do not, of course, apply to the DC voltage range.

Owing to the characteristics of the rectifier, indications of AC volts below about 1 volt are inaccurate. This should be remembered when working near the lower end of the range. Also, the readings shown on the meter may be less accurate than the readings shown on the meter. This range can, however, be used for the detection of small AC voltages where their actual values need not be known. These limitations do not, of course, apply to the DC voltage range.

Rear view of the practical instrument, the circuit of which is given in Fig. 6

variable resistor R10a to enable full-scale deflection to be reached until the battery potential has fallen to 1 volt.

Operation
The operation of the instrument requires no special comment. Test leads are simply connected to the common terminal and the terminal appropriate to the range desired. Correct polarity should be observed on DC and the selector switch set to the required position. When in any doubt as to the right range, always use the highest one to start with. If the deflection is less than one-tenth of full-scale, the connectors may then be changed to the next lowest range.

Owing to the characteristics of the rectifier, indications of AC volts below about 1 volt are inaccurate. This should be remembered when working near the lower end of the range. Also, the readings shown on the meter may be less accurate than the readings shown on the meter. This range can, however, be used for the detection of small AC voltages where their actual values need not be known. These limitations do not, of course, apply to the DC voltage range.

For those who wish to fit compensating shunts for the AC and DC voltage ranges, as described earlier, reference should be made again to Fig. 4. R9 should be connected between the "common" terminal and the "DC" tag on switch pole S3 (which may be seen in Fig. 6). R9 can be connected directly across the DC output corners of the bridge rectifier (marked + and - in Fig. 6). As mentioned before, the use of such resistors modifies the effective internal resistance, Rm, of the meter and thus alters the lowest available current range. The values of all the resistors also have to be re-calculated.
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